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THESIS

PERUVIAN WEAPON SYSTEM
ACQUISITION PROCESS

by

Arnaldo Cuba y Escobedo

December, 1990

Thesis Advisor: William J. Haga

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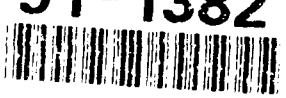

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Peruvian Weapons Acquisition Process

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ABSTRACT

Historically, the acquisition of a weapon systems in the Republic of Peru has been made on the basis of system effectiveness and initial acquisition cost, with little or no consideration being given to operating and support costs that will be incurred after the system is deployed in the field. Peru acquires most of its sophisticated weapon systems from foreign countries, under this situation, broad understanding of Life Cycle Cost (LCC) concept and techniques are needed.

This Thesis introduces the LCC concept, life cycle costing techniques and the methodology for Life Cycle Cost analysis in Peruvian Weapon Systems acquisition process. The research aims to show the effects that United Foreign Military Sales has in the Third World, the Technology Transfer as a decisive influence on the daily lives of most of the world population and The Soviet Union's Arms Trade With The Third World, the Life Cycle Cost Concept in Peruvian Weapon acquisition process, and its fit into known economic analysis techniques.

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I. UNITED STATES FOREIGN MILITARY SALES

A. HISTORICAL PERSPECTIVE

Since the arrival of the industrial revolution, armament sales were an integral part of world trade. Arms merchants such as Alfred Krupp of Prussia and Lord Armstrong of England survived in their early years only because of foreign purchases [Ref. 1]. While most modern weapons manufacturers are less dependent upon foreign sales for their survival, Foreign Military Sales (FMS) are a lucrative trade. From a few billion dollars in the early 1960s, the value of weapons deliveries culminated at more than $38 billion in 1982 and 1983 [Ref. 2]. In the early 1900s, the U.S. Government was not extensively involved in FMS as an instrument of foreign policy. Yet, American companies profited from foreign sales of munitions and military equipment. Du Pont sold gunpowder to Spain and Latin American nations battling for their independence and to both Russia and Britain in the Crimean War.

Armaments sales became more of an instrument of foreign policy with the commencement of World War II. By late 1939, the Lockheed aircraft company was delivering bombers to the British Royal Air Force under the largest order yet given an American aviation firm [Ref. 3]. In 1940, President Roosevelt sent 50 destroyers to Britain. The Lend-Lease Act of 1941 created a channel for the American government to funnel military aid to its allies [Ref. 4].

The cold war increased the government's coordination of weapons exports. Faced with an increasingly antagonistic relationship between the world's new "superpowers," President Truman believed that "collective security" would defend the Free World. On March 12, 1947, Truman dedicated the United States to the military and economic assistance of threatened nations around the globe [Ref. 4: pp. 714-716].

Until the late 1950s, security assistance efforts enjoyed widespread support and generated little controversy. Still, President Eisenhower was suspect of the "Military Industrial Complex" and support for aid was reduced under his administration [Ref. 4: pp. 738-744]. Further, critics of the grant aid military program labeled it a "giveaway" that the U.S. could not afford. Thus, Congress cut the program and shifted some grant military aid to loans.

By the early 1960s, the political map was more stable. The Berlin Wall and the Cuban missile crisis passed without military conflict. In the United States, a rising unfavorable balance of trade appeared. President Kennedy reduced grant military aid even further, placing greater emphasis on economic assistance. Kennedy wanted Western Europe to buy more U.S. arms and stated that "the government must play a more vigorous part in helping to enlarge foreign markets for American goods and services." The government should "urge the purchase of new weapons and weapon systems by those of our allies who are financially capable of doing so [Ref. 3: p. 20]."

About 1965, President Johnson increased foreign armament sales due to the conflict in South East Asia and insurgency movements in Latin America [Ref. 4: pp. 772-776]. This escalation of arms sales initially caused little reaction and some have stipulated that the involvement of governments helped to muffle any public concern. However, the decade would not end without widespread questioning of American arms export practices.

In 1969, President Nixon noted that the U.S. should maintain treaty commitments and a willingness to provide security assistance. Yet, the U.S. should "look to the nation directly threatened to assume the primary responsibility . . . for its defense [Ref. 3: p. 21]". To reduce the U.S. presence abroad and shift more of the responsibility for defense of other nations onto those countries themselves, the Nixon Doctrine increased privileges and credits for arms sales.

In mid 1977, President Carter announced new guidelines for U.S. arms exports in Presidential Directive, PD-13. Carter said "the virtually unrestrained spread of conventional weaponry threatens stability in every region of the world." The administration would view arms transfers as "an exceptional foreign policy implement, to be used only in instances where it can be clearly demonstrated that the transfer contributes to our national security interests [Ref. 3: p. 24]".

In the 1980s, President Reagan's approach to arms trade was nearly the complete opposite. To more easily use arms transfers as a policy tool, Reagan dropped the annual ceiling on arms sale levels, rescinded restrictions on U.S.

embassies and military missions abroad concerning foreign arms sales, and created a Special Defense Acquisition Fund (SDAF). The Department of Defense (DOD) uses this fund to purchase large quantities of military equipment, at a more economical rate, in anticipation of future arms sale agreements [Ref. 3: p. 29].

B. STATUTE AND CONSTITUTIONAL CONTROL OF FMS

Among the first major statutes to control foreign military sales was the restrictive Neutrality Act of 1935, designed to keep the U.S. out of European conflicts. This law was a failure and Congress repealed it in 1939 [Ref. 4: pp. 661-666]. The FMS program as we know it had its origin in the Lend-Lease Act of 1941. As the GAO noted then, " . . . the U.S. government converted arms transfers from predominantly private to predominantly public channels [Ref. 3: p. 18]". However, Lend-Lease did not extend into the post-war era.

The post-war funded transfer of arms began in 1947 when Congress granted $400 million in economic and military aid for Greece and Turkey. As the cold war grew, Congress placed the grants and sales of military equipment into the Mutual Defense Assistance Act of 1949 [Ref. 4: pp. 714-718]. This authorized FMS cash and credit programs until Congress passed the Foreign Military Sales Act.

The Foreign Military Sales Act of 1968 established separate authority for foreign military sales and made some procedural reforms. The act distinguished between sales and grants, removed cash and credit arms sales from the Military

Assistance Program (MAP), gave the FMS program separate legislative authority, and expressed some of Congress's growing concerns about arms exports [Ref. 3: p. 21].

In 1976, the International Security Assistance and Arms Export Control Act (AECA) established comprehensive control of exports and imports of military weapons. The AECA instructed the President to tell Congress what items he desired to control and set two channels for arms sales, direct commercial sales and FMS [Ref. 3: p. 29].

The 1981 Foreign Aid Authorization bill repealed the 1976 AECA direct commercial sales cap, reduced Legislative Branch oversight of arms sales, and loosened the reporting requirements for sales to NATO and other allied nations. The bill also reduced the requirement for advance notice to Congress for arms sales from 30 to 15 days and revised the dollar amount of the notification threshold [Ref. 3: p. 29].

As designed, the Constitution of the United States controls the budget process. The Department of State, Office of Management and Budget (OMB), DOD, and the National Security Council (NSC) review the FMS budget before its submission to the President for inclusion in the annual budget request to Congress [Ref. 3: p. 45].

The Senate Foreign Relations and House Foreign Affairs Committees are responsible for authorizing and appropriating funds for the security assistance programs. With the preliminary approval of these committees, the budget

committee in each chamber can pass a first budget resolution, setting congressional targets for subsequent authorizations and appropriations. As with any budget process, the authorizing committees then scrutinize the foreign aid bill and key on countries receiving the largest portion or requesting significantly different aid from the previous year. Congress completes action on the budget when the Appropriations Committees and then both houses vote to provide funds [Ref. 3: p. 45].

Congress divides the security assistance budget into five major elements [Ref. 3: p. 21]. Foreign Military Sales Credits (FMSCR) is the largest Security Assistance Program (SAP) element and has the most impact on total arms exports. This program finances weapons acquisitions of foreign governments unable to pay in full at the time of agreement or who deserve financial assistance for another reason.

Other programs are: The Military Assistance Program (MAP), which provides grants to foreign governments to use to obtain military equipment and services; the Economic Support Fund (ESF), which aids in financing other than military projects; the International Military Educational and Training (IMET), which provides grants to pay U.S. forces to train foreign military personnel; and the Peacekeeping Operations (PKO), which is the smallest of the five programs and provides funds to support designated peacekeeping operations.

Marginal funding levels, specifically designated country funding levels, and an increase for funds provided as grants, vice loans, characterize recent FMSCR

policy decisions. Traditionally, FMSCR monies have fallen into two pots. Earmarked funds set minimum required funding levels for specific countries receiving FMSCR financing. Discretionary funds are those the President may use as he sees fit. Increasingly, Congress exerts significant influence over the disbursement of FMSCR funds and earmarks the FMSCR funds, leaving little discretionary funds available [Ref. 5]. The 1989 Foreign Operations Export Financing and Related Programs Appropriations Act set floors for aid to Israel and Egypt, ceilings on aid to Pakistan, and barred aid to Contra forces in Nicaragua [Ref. 6]. In 1989, Congress earmarked 99.75 percent of the entire FMS appropriation for seven countries and ended several unprotected programs.

In 1989, the FMSCR program became the Foreign Military Financing Program (FMFP) and Congress identified funds as either grants, or loans [Ref. 7]. In 1990, FMFP became Foreign Military Sales Financing (FMSF). President Bush requested $5.027 billion in FMSF financing, all in grants [Ref. 6: p. 28]. Promoting peace in the Middle East and maintaining democracy in Central America and the Philippines are the purposes for most of the program. Cash sales of military equipment made either through the FMS cash program or through commercial channels are not part of the federal budget. However, they remain a significant part of FMS [Ref. 5: p. 19].

Decisions of the Supreme Court also influence U.S. arms export policy. In 1983, the Court ruled the legislative veto power of the Foreign Military Sales Act

was unconstitutional and unenforceable. The act allowed Congress to block an arms sale by a straight forward majority vote in each house. It was not subject to the President's review nor veto [Ref. 3: p. 47]. Now, under an amended act, Congressional rejection of an arms sale requires the passage of a joint resolution, signed by the President. Overriding an Executive Branch veto requires two-thirds of the votes in both the House and Senate. The Executive Branch needs only one-third of the votes plus one in either of the houses to sustain its veto.

C. JUSTIFICATION OF FOREIGN MILITARY SALES

Until the early 1900s, most Americans saw arms sales as a commercial activity no different from any other form of commerce. This view lost favor among the general population in the post-Vietnam era. Nonetheless, President Reagan resurrected this view when he directed that "U.S. government representatives overseas will be expected to provide the same courtesies and support to firms that have obtained licenses to market items on the U.S. munitions list as they would to those marketing other American products [Ref. 3: p. 55]. To the President, arms sales were central to North American national defense, political well being, and economic development.

FMS aids national security by strengthening U.S. allies and friends while deterring unwanted conflict [Ref. 4: pp. 715-716]. Arms transfers enhance the security of nations and promote stability in regions where changes in the balance of power would adversely affect the U.S. FMS gives defensive capabilities to allied and friendly governments and enables them to assume the military burden

that the U.S. previously carried. FMS deters external aggression and suppresses internal revolt. FMS is central to South Korea's defense of its independence and is vital to Taiwan's and Israel's survival.

FMS advances U.S. political interests as it promotes U.S. influence over foreign political and military leaders and provides a tangible demonstration of U.S. commitment to their nation [Ref. 3: pp. 60-63]. Additionally, FMS gives leverage in other ways. Nations that purchase weapons, especially modern sophisticated systems, often remain dependent upon the U.S. for spare parts, ammunition, and various technical services and training. This pressures the recipient to support U.S. regional political initiatives. Somalia's agreement not to intervene in the Ethiopian Civil War and allow the U.S. to use bases in Somalia is a direct result of the political influence of FMS [Ref. 3: pp. 60-63].

FMS also generates important economic benefits at three levels of the economy [Ref. 8]. Arms sales are a source of foreign exchange and improve our balance of trade. FMS also assures the health of the U.S. defense industries and lowers the costs of procurement for the U.S. armed forces. FMS reduces domestic outlays for weapons production. With FMS, manufacturers can pass part of the research and development costs onto the foreign buyer and achieve better economies of scale through larger production runs.

D. IMPACT UPON THE THIRD WORLD

Unlike Western Europe where FMS contributed to more than forty years of peace and stability, in the Third World arms sales do not secure national security

objectives, extend political influence abroad, nor support the American economy. On the contrary, U.S. arms exports fuel regional arms races, make wars more likely and more destructive, foster human rights abuses, and lead impoverished Third World nations to divert funds from economic development.

1. Arms Trading and Regional Conflict

Instead of providing Third World nations with additional security and promoting regional stability, arms transfers intensify mistrust and fear, breed regional arms races, and heighten the potential for conflict. In a seemingly perpetual cycle, the purchase of new, technologically advanced weapons lead regional adversaries to counter-purchase other advanced technology. For several reasons, this vicious cycle is difficult to slow, much less halt, once set in motion.

Convoluting and exacerbating the effects of the arms buildups, security for one nation heightens the paranoia, justified or otherwise, of a rival nation. This paranoia exhorts the rival to initiate weapons transactions on the mere inkling of another nation's purchase. Also, difficulties in obtaining information and quantifying military strength leads rival nations to assess each other's military needs and strengths very differently. One nation's desire to establish military parity is another nation's attempt to gain an advantage.

If such insanity was not sufficient, the considerable delay between time-of-order and time-of-arrival for the arms heightens tensions as nation A buys weapons "anticipating" the purchase by nation B, who purchases the weapons "anticipating" the arrival of weapons to nation A. Then, of course, nation A

receiving the weapons becomes justification for nation B to buy new weapons, which then becomes justification for nation A to begin another cycle as well.

Another complicating factor is the desire of a nation to modernize its forces. Rarely can a Third World nation replace old, obsolete weapon systems with the same or similar models. Much like the Amish in Pennsylvania searching for replacement bearings for their wagons, the parts they want are modern, new and improved version of the original [Ref. 9]. However, new and improved means more lethal and that initiates another arms race. Even more damning than the arms race is the destructive power of new, sophisticated weapons. Regional conflicts are considerably more destructive as the use of the new, wire guided anti-tank rockets proved in the few weeks of the 1973 Arab-Israeli war.

While it seems insane and self-defeating for Third World nations to involve themselves in a self-propelling arms-race, dropping from the race has a very serious implication. The first nation unilaterally to back down concedes to his rival superior arms.

As a peace promoting policy, FMS is a failure. While arms sales provide the U.S. with some leverage to prevent wars, this leverage is temporary, at its best. Having armed Israel for more than forty years has not resolved the political problems of the Middle East nor restrained Israel from repeatedly invading its neighbors. Arms transfers to Argentina did not provide the U.S. with sufficient influence to prevent nor resolve the Argentinean invasion of the Falkland Islands. Soviet contacts within Libya didn't stop its invasion of Chad.

Argentina and Libya are only two of many nations whose military equipment exceeded their legitimate self-defense needs and thus permitted otherwise implausible military invasions. The largest recipients of both U.S. and Soviet assistance, Iran-Iraq, Somalia-Ethiopia, Egypt-Israel-Syria, and India-Pakistan ultimately went to war.

2. Arms Sales and Human Rights

United States' arms transfers to Third World countries foster human rights violations. By providing weapons for entrenched, anticommunist governments, the U.S. signals its approval of the regimes and supplies them with weapons that are *not just ideal for aggression against rebel forces, but also ideal for the repression of dissident forces.* For example, in 1979, Third World police forces alone received 615,000 gas grenades, 126,000 revolvers, 52,000 rifles and submachine guns, 12,000 canisters of Mace and 56 million rounds of ammunition [Ref. 10]. This does not include the even larger quantities of similar weapons we shipped to Third World military organizations.

3. United States Initiatives

Each American President since President Kennedy has acknowledged the objections of human rights advocates. In 1964, the U.S. barred South Africa from receiving U.S. arms because of its human rights practices, (although loopholes in this ban allowed South Africa to purchase $35 million worth of U.S. arms between 1964 and 1978) [Ref. 11]. However, this type of enforcement was not

widely used until 1973 when Congress launched a true campaign to create linkages between arms transfers and human rights.

Congress declared in Section 32 of the 1973 Foreign Assistance Act:

> "It is the sense of the Congress that the President should deny any. . . military assistance to the government of any foreign country which practices the internment or imprisonment of that country's citizens for political purposes [Ref. 12]".

Using the power of this act, in 1974, Congress reduced military aid to Korea and Chile because of human rights abuses. To provide additional linkage between human rights and weapon sales, Congress adopted the following compromise language in Section 502B of the Arms Export Control Act of that year:

> "It is further the policy of the United States that, except under circumstances specified in this section, no security assistance may be provided to any country the government of which engages in a consistent pattern of gross violations of internationally recognized human rights [Ref. 12].

To prevent military equipment from becoming tools of repression, Congress placed specific language in the Foreign Assistance Act of 1974 to forbid the use of FMS channels to supply internal security forces. Yet, U.S. Congressional attempts to use FMS to encourage human rights have failed for several reasons:

First, there is no internationally defined and universally accepted definition of human rights. Human rights to a *campesino* trying to eke out an existence in a Central American jungle and human rights to his urban cousin in the capital city are worlds apart.

Second, standards set by North Americans do not necessarily fit the requirements of Third World inhabitants. The Americans' idea of individual rights is not generally held in the Third World. Freedom from economic want or freedom from anarchy and lawlessness may be their most cherished right and may far exceed their desire to participate in free elections [Ref. 13].

Third, foreign governments can ignore and get around U.S. law with impunity because the U.S. lacks international enforcement mechanisms. Thus, repressive branches of internal control organizations continue to receive American defense equipment [Ref. 10: p. 186]. Besides, since the military in the Third World is often as involved in repression as are police and internal security forces, the law, even if enforced, would be ineffective.

Last, Third World nations keenly remember and deeply resent every instance of "Yankee aggression." They view American's imposition of human rights standards and sanctions for human rights violations as another example of imperialism and interference in their internal affairs.

4. Arms Transfers and Third World Economic Development

Arms sales and transfers affect on the economic development of the Third World. Arms sales to Third World nations impede their development, tie up badly needed resources and foreign exchange, and produce no consumable goods nor provide significant employment.

5. Arms Imports and Third World Debt

Arms transfers dismally affect the developing nations' balance of payments, exhaust badly needed foreign currency, and aggravate the debt crisis of many Third World countries. The ramifications are serious. Some Third World nations have seen their real incomes plunge by as much as two thirds since 1980. Others, having fallen behind on their repayments, may reject their massive debts. This could trigger a worldwide financial crisis [Ref. 14].

Developing nations spend $25 to $30 billion on arms imports each year, a significant drain on foreign exchange. Five of the 15 largest debtor nations, Argentina, Venezuela, Nigeria, Morocco and Peru, were among the 20 leading arms importing countries between 1981 and 1985 [Ref. 15]. The 15 largest debtor nations imported more than $12 billion worth of arms between 1979 and 1983 [Ref. 2: pp. 131-134]. A quarter of the accumulated Latin America debt is due to arms imports [Ref. 15: p. 97].

Arms transfers are largely unproductive with few beneficial effects for the economy. According to the United Nations, arms promoters exaggerate and misplace spinoff benefits of arms imports [Ref. 16]. Most of the infrastructure that the military creates makes no contribution to the civilian economy of an underdeveloped nation. Particularly in Third World nations, the military technology is too specialized for civilian applications and does not apply to civilian industries. Even when partial production runs occur within Third

World countries, arms production is capital-intensive and ill-suited for labor surplus economies of the Third World.

6. Diverting Resources from Social Development

Using arms import programs to provide an impetus for the development of infrastructure and the training of large quantities of civilians is inefficient. A Third World nation could more readily accomplish these objetives by directly channeling the resources into development. Instead of buying weapons from the U.S., the Third World nation could pay our own people to build roads, dams and airports for civilian use.

Hard currency is the most crucial of the diverted resources. Developing nations spend approximately $25 to $30 billion a year to purchase arms [Ref. 15: p. 97]. This figure does not account for maintenance costs that typically run five times the original purchase price over a 10 to 20-year life span. Often, this drain becomes so great, that the Third World nation must defer maintenance on the aircraft and ground them. The grounded aircraft not only deprive the nation of the alternative use of the money, but also stops the nation from meeting its legitimate security needs.

II. TECHNOLOGY TRANSFER AND THE SOVIET UNION'S ARM TRADE

A. INTRODUCTION

As the US and USSR made tactical nuclear weapons with massive force and hardened retaliatory delivery systems, these weapons assured that war between the two nations would bring their mutual destruction. Eventually, using nuclear weapons became nearly unimaginable and a direct military confrontation between the superpowers seemed less likely.

In this environment, the early 1980s presented unexpected changes and new opportunities for the United States and the Soviet Union. Occurring in quick succession, the deaths of Leonid Brezhnev, Yuri Andropov, and Konstantin Chernenko left a void in Soviet leadership. Into this void came Mikhail Gorbachev. With Ronald Reagan's sudden willingness to embrace the "evil empire," Gorbachev's willingness to release the Soviet's hold on some satellite nations seemed to signal the end of the Cold War.

Between the superpower stand-off and the changing leadership of the US and USSR, direct military competition seems less remote. While this might mark the beginning of an era of East - West cooperation, it may also signal an era of intense economic competition between the United States and the Soviet Union. If so, the competition will accelerate as the US and USSR inevitably deplete their

supplies of unrecoverable natural resources and former East Bloc nations penetrate further into world trade.

The idea of fierce East - West economic competition is not new. In 1957, Soviet Premier Nikita Khrushchev said that war with the US was not a military confrontation....it was an economic confrontation. He said:

> "We declare war upon you . . . in the peaceful field of trade. We declare a war. We will win over the United States. The threat of the United States is in the field of peaceful production [Ref. 17]".

If the US and USSR base their further and main competitive nature on economic strength, the US trade policy with the Third World must include an economic and military evaluation of the effects of trade. The US must fully understand the intentions and effects of Soviet world trade.

Within the last thirty years, the Soviet Union developed the capabilities to extend credible economic influence through trade and aid. Within the last 20 years, we have seen an accelerated decline in the perceived Soviet military threat to Western Europe and one could debate whether the Soviets ever posed a military threat to the Third World. This encourages regional détente and that promotes increased East-West European trade.

Economic development, not Soviet military envelopment, is the immediate concern to most world leaders. In the early 1970's, the Soviet Union saw the economic and political benefits of world trade and broke from their traditional autarkic views. In the arena of world trade and in search of much needed

technology and grain, the Soviets initially focused on and enjoyed the benefits of trade with the West. Moscow is now gradually enlarging trade activities and shifting their attention to Third World markets to obtain both economic and political gain.

Three complementary factors drive the Soviet Union's entry into world trade. First, and most importantly, is the Soviet Union's inherent need to expand continuously their influence and power. Traditional Czarist Russian expansionism and modern Communist ideology and doctrine support this need. The Soviets realize the expansion of power and influence via three basic channels, the expressions of state power and influence through state diplomacy, the military, and economics. While previous kremlin leaders failed to note much of the strength and importance of economic involvement, such involvement now holds an increasing role in Soviet world strategy.

The economic and political benefits of trade is the second factor driving the Soviets into world trade and the new Kremlin leadership. The growth and development of East-West European trade with the resultant regional continuation of détente further moderates Soviet behavior. The increasing costs involved in the extraction of domestic natural resources and the need to open markets for Soviet semifinished and finished products encourages expanded trade with the Third World.

The recent failure of the Japanese to lower barriers to US farm products and the US and European Economic Community (EEC) failure to eliminate farm

subsidies shows the limits of the world's free market system. With persistent protectionist sentiment throughout the world, the Soviet Union's entrance into Western and Third World markets could eventually place additional competitive strains on the US and world free market system. Moreover, many former and emerging East bloc nations such as Rumania, Bulgaria, Poland, and Yugoslavia essentially retained all or much of their command economies. As these nations foray into the world market, they could spark trade protectionist wars further debilitating the world's free market system. Such East European ignited protectionist battles would inevitably reduce US economic power and influence.

As the Soviet's economy remains somewhat isolated, they can watch the battle from the sidelines. Despite recently publicized troubles at home, the Soviet Union's economy is almost self-sufficient. As such, the Soviets can enter and develop world markets selectively, content with the knowledge that they are not dependent on those markets. At the same time, the Soviets are well aware of the US's dependence on Third World markets [Ref. 18]. Lenin viewed the fundamental weakness of the capitalist system in its dependence on the colonies and developing countries. The road to London stretched through New Delhi and Peking in 1920. Today, in the neocolonial period, the road to Washington stretches through South Africa, Saudi Arabia, the Philippines, Peru, Venezuela, Panama and Mexico, among others.

B. TECHNOLOGY TRANSFER DEFINED

The meaning of technology transfer depends on the time you make the transfer, the people considering the transfer process, and the intended usage. For this thesis, technology transfer means:

> The process by which one country adapts for its own use technical information originating in another country [Ref. 19].

The key words are "adapted" and "technical information." This study uses a broad idea of technical information in the sense that Schon [Ref. 20] defined as:

> Any tool or technique, any product or process, any physical equipment or method of doing or making by which human capacity is extended.

Technology transfer is more than just distributing technological information; it is a concerted distribution of information in quantity, quality, and format for use by the recipient. Doctors [Ref. 19 p. 7.] stated that we should view technology transfer as a political, social, and economic problem. Although many papers explain technology transfer and some researchers have conducted field studies, obtaining meaningful information on the process of transfer remains allusive.

Technology transfer may be either vertical or horizontal in nature. A vertical transfer is the application of a technical principle to produce a new product or process within the organization or discipline. Horizontal transfer is

the application of a technical principle to products or processes in another discipline or institutional setting. Most nations use the vertical transfer.

Simply put, technology transfer is the application of technology to a new use or user. The transfer employs technology developed for one purpose in a different application or a new user. This involves the increased use of the existing science-technology base in new areas of application as opposed to its expansion by further research and development (R&D). Technology transfers spur productivity growth in the existing science-technology base.

The time span for the transfer can extend from a few days to a number of years. You can directly apply the technology in its existing form to the new environment or the process, or you can extensively modify or redesign the technology or use adaptive engineering to make the technology fit its new role.

Depending on the nature of the technology and the specific circumstance prevailing in each case you can use a variety of means to transfer technology. Methods range from licensing agreements, joint ventures, and turn-key factories to technical consulting, product sale, trade exhibits, and personal contacts. No single method is appropriate for all situations and the effectiveness of the different approaches varies with the ability of the recipient to learn the increased technology. Generally, methods that involve considerable person-to-person contact and some measure of education and training are more effective. Successful technology transfer depends on developing effective communication between the principal parties, although, effective communications alone is not

sufficient. Many other technical, economic, and social factors bear on the eventual outcome.

Technology transfer is not new. In the thirteenth century, Marco Polo introduced Chinese inventions such as the compass, paper making, and the use of coal for fuel to the western world. Yet, only recently have we concertedly and systematically used technology transfer to stretch the R&D investment, develop greater usage of the existing science-technology base, and generate greater economic impetus.

Technology transfer offers the opportunity to obtain a greater return from past investment in R&D, but is not an end in it self. Its importance lies in its ability to stimulate and strengthen the innovation process. As such, technology transfer gives the means to increase the rate of technology innovation. Understanding the importance of technology transfer in the innovation process requires a close look at how technology transfer interrelates with innovation.

Industry devotes much attention to better managing the country's considerable technological resources. Technology transfer and technological innovation represent two different aspects of the general subject. Although each topic individually enjoyed wide attention in recent years this attention often neglected the interrelationship between technology transfer and innovation. Examining the interrelationship gives a better understanding of how these two ideas affect one another. Viewed in their proper perspective, you can gain a better appreciation of their importance on the national scale.

Because of the many definitions and interpretations of the meaning of technological innovation and technology transfer, this study discusses the two individually to clarify their meaning. As innovation and technology transfer are subject to much research now. Their definitions vary from researcher to researcher.

1. Innovation

Innovation is the action that delivers an invention or idea to its first acceptance and use. Internal factors such as economic and political climate, competition, public opinion, market conditions, company management policy, and the availability of financial resources influence innovation. Thus, the innovation process generally is evolutionary in nature and often spans many years. Innovation does not confine itself to the technological sphere but also extends in the arts, educational, social, military, and political circles.

Technological innovation is the process of taking an idea, or invention, and developing a useful product, process or technique that gains initial acceptance in the marketplace or user community. The wide diffusion of an innovation throughout the market it serves, further technological improvement, and its further adaptation to new applications occur after its acceptance. This period is the post innovative period [Ref. 21]. This is the institutionalizing period. The generation of an idea or invention is not the sole initiation of innovation. The recognition of a need or technical opportunity also stimulates innovation. Most successful innovations arise from need recognition and not from idea generation

or intervention. That is, demand-pull and not technology-push was the stimulus for many successful innovations. This does not imply that inventions and idea generation are not important in the innovation process. On the contrary, although need recognition is a major stimulus for first conception in most successful innovations, many of these may not have succeeded without the benefit of inventions and ideas developed during the innovative period.

Because innovation is subject to many internal influences that the innovator does not control, serendipity and luck play a significant role in determining success or failure. So, the innovation process develops an evolutionary nature that is not amenable to strict management and control. This is evident by the relative disparity in time spans between first conception and first realization of successful innovation. Besides, the innovative period varies for different industries, technologies, product type, and means of financing [Ref. 22]. Thus, environmental factors decide to a large degree the chances for a success or failure of a particular innovation. Alternately, you greatly enhance the chance for successful innovation if you establish an environment conducive to innovation.

2. Technology Transfer

Technology is the application of science. Yet, this definition is inadequate. For instance, you may construe the dropping of a pin from your hand to the floor as an application of the law of gravity, but it does not show technology. The imprecise nature of technology rules against a precise definition. Distinguishing technology from science will help define technology. Whereas science deals with

the increase of knowledge and understanding, technology deals with use. Whereas scientific research usually results in the publication of a paper, the output of technological activity is a product, process, technique, or material developed for some specific use. Technology not only involves the application of science but also can incorporate inventions and additional research to some extent. Patents are more commonly the outgrowth of technology, not science.

The phrase technology transfer also suffers from ambiguity, partly because of the imprecise nature of technology, and partly because the word "transfer" leads to the question, "from where and to whom?" It implies the existence of a source of technology and a recipient or user. The technology source and the user are not necessarily within the same technical discipline, Thus, technology transfer may point to an interdisciplinary activity requiring knowledge in several fields. The activity involves the increased use of a proven technology base not its expansion through further research and development.

For this thesis, technology transfer is a key element of defense. The transfer of technology from the US and USSR is a primary tool that Peru considers when developing a defensive military strategy. How Peru can employ the technology is of major concern to policy-makers who formulate foreign policy. Because the US and USSR can provide advance technology with small up-front costs, employing US and USSR developed technology draws particular interest.

C. THE SOVIET UNION: ARMS TRADE WITH THE THIRD WORLD

The maintenance of a military is important to Third World nations for various reasons. Whether the threat actually exists, the *perceived* external threat is probably the foremost reason to raise an army and maintain an adequate defense posture. How large, well-equipped, and trained is a nation's military, largely depends on the nation's resources and its commitment to maintain a strong defense posture.

A useful way to categorize Third World nations is to call nations that produce arms, "producers," and those that do not produce arms, "non-producers." Israel, India, Egypt, South Korea, Brazil, Chile, and Argentina are some arms producing Third World nations.

This chapter examines the Third World defense industries and their association with Soviet technology. This is important as even indigenous arms producers do not produce all the weapons that they want. Sometimes, they obtain much of their additional arms from the Soviet Union. For example, India produces Soviet designed weapons via license. It is possible that the Third World has incorporated Soviet technology into their indigenous production.

Additionally, linkages exist between the Third World arms producers, Western technology, and the Soviet Union in their role as the middle-man. This happens either through arms exports that assimilated Western technology or by cooperative joint ventures, such as licenses, that allow production of arms that have Western technology assimilated into them.

On the other hand, the Third World benefits from Western technology in the products it buys and through its own indigenous production via license or reverse engineering. For example, through the overt and covert importation of advance technology, the Iraqis took an unreliable and inaccurate, surface to surface missile and made it a weapon of importance in the Middle East. The threat of a chemical weapon-Scud missile attack has altered US tactics in the Middle East. Were Iraq to outfit the Scud with a nuclear payload, it could undermine US military efforts in the region.

Arms transfer is a multi-billion dollar business and the Third World is a large contributor to the revenue that an arms exporter receives. Whynes attributes the rationale for Third World defense expenditures, and the reasons why it has grown, to certain factors. Summarized [Ref. 23], they are:

1. Security
2. Internal repression
3. The influence of the budgetary process
4. The existence of a military-industrial complex
5. The vested interests of the military establishment
6. The needs of ideology and national identity
7. Imperialism

The Soviet Union remains a major arms supplier to the Third World. Of particular interest to this paper are those Third World nations that have imported and license-produced Soviet weapons that may incorporated Western technology.

The Soviet Union's involvement in the Third World dates from its conception as a nation. The Soviets regard developing nations as in the sphere of influence of the Soviet Union. Even today, while the Soviets have taken some steps to revamp their economy, the Soviets consider themselves to be the center of the world communist movement. The historical inevitability to convert the world, starting with nations not entrenched in the Western free market system, those that are not capitalist, guides this ideology. Thus, Soviet theoreticians traditionally have considered the Third World natural allies of socialism [Ref. 24].

As Third World nations began to get their independence, the Soviets modernized their doctrine to support the national liberation movements, and the quest to be independent of West. The Soviets adopted this new tactic after Stalin's death. They saw the importance of the Third World because of its resources and as a way to stop or reverse Western influence. The major difference of the post-Stalin period is that the Soviet Union could now have friendly and mutually beneficial relations with Third World nations even if they were not socialist.

Much of the Third World was receptive to Moscow's new policy toward developing nations [Ref. 24], due to the attractiveness of Soviet military assistance and the comparatively low prices and favorable terms for weapons [Ref. 24: p. 86]. The going rate for a MiG-23 was $6.7 million when Israel was paying about $12 million for a F-15, and the MiG-21 was selling for $2 million when the F-4 was

selling for $5.7 million [Ref. 24]. Soviet financial terms included a grace period of one to three years with repayment periods averaging ten years at two percent interest [Ref. 24].

Still, time has eroded these advantages. The US Department of State estimates that since 1977 or earlier, Soviet arms prices increased. As of 1982, they were roughly equal or sometimes higher than for similar Western weaponry [Ref. 25].

Expedience is an important factor to a Third World nation. If prices and terms an equal between the Soviet Union and the West for comparable weaponry, one clear advantage the Soviet Union offers a Third World client is the speed with which it can fill an arms order. This advantage results from the capacity of the Soviet arms industry. It allows Moscow a significant advantage over the rest of the arms producing world [Ref. 25: p.8]. There are two clear advantages the Soviet Union gains frome very Soviet arms sale to the Third World. First is he political influence it exercises over the buying nation. Second is the hard currency it generates from the sale. For example, the CIA estimated that the Soviet Union earned approximately $1.5 billion dollars in hard currency from arms sales in 1977 [Ref. 25: p. 7].

The political success of the Soviet Union's arms sales program is questionable. Still, Pajak believes:

> ". . . of the various types of foreign assistance employed by the Soviets military, economic, and technical aid has proven to be the most dramatic and consequential. Besides directly contributing to the emergence, growth, and survival of nonaligned regimes, arms aid has

fostered an image of the Soviet Union as a benign but powerful anti-colonialist power. It has served as the primary Soviet vehicle for acquiring influence in regions important to Western interests, often providing the Soviets with political entree into countries where their role had hither to been limited or nonexistent. Furthermore, military aid has often provided the opening wedge for a variety of diplomatic, trade, cultural, and other contacts which have been difficult or impossible to achieve otherwise, such as in the Arab countries in the 1950's, India and Indonesia in the 1960's, and Ethiopia and Peru more recently [Ref. 24: p. 393]".

III. LIFE CYCLE COST CONCEPT IN PERUVIAN WEAPON SYSTEM ACQUISITION

A. BACKGROUND

Traditionally, military procurement emphasized unit cost as the major determining factor in weapon system acquisition. Often to the dismay of the buyer, after they placed the systems into operation, their operating and support costs (O&S) rapidly increased. The cost of operating and supporting systems over their useful life is often several times greater than the initial acquisition price.

Recently, the U.S. military increased their use of Life Cycle Cost (LCC) for new weapon systems in order to reduce rising acquisition costs and operating and support (O&S) costs. Including future costs as part of the decision criteria makes sense. Increased consideration of O&S costs in various design and support decisions can reduce the overall O&S costs. Since the objective is to reduce LCC, that is total cost, you must give equal emphasis to all costs: research and development, production, and O&S.

The dilemma of budgeting constraints, a constant and formidable threat from neighboring countries, counter-insurgency requirements and a desire for sophisticated weaponry is a dilemma confronting Peru. As a Third World country, Peru faces difficult decisions trading off military strength and economic growth. Historically, the Republic of Peru based their acquisition of weapon

systems on system effectiveness and initial acquisition cost. They gave little or no consideration to O&S costs that they would incur after they deployed the systems.

Each year, Peru spends about 12 percent of its GNP, representing one-third of the national budget, on defense. Peru spends about one-third of its defense expenditure on equipment maintenance. Peru still acquires most of its sophisticated weapon systems from foreign countries. This pressures Peru to reduce defense spending and encourages them to try new approaches to managing weapon systems acquisition and O&S costs.

During the acquisition stage, if Peru does not consider O&S costs, the unbudgeted future O&S costs of a new system will confront the Peruvians. If they allow this pattern to continue, they will allocate the bulk of their annual defense budget to support existing systems. This will reduce or delay future acquisition programs.

This chapter introduces the LCC concept within the Peru military and describes the application of the LCC application methodology. Peru acquires all of its sophisticated weapon systems from other countries. These systems have already been developed, tested, produced and deployed. Therefore, this study devotes itself to the life cycle cost approach, focusing on logistics, as a criterion for selecting the preferred alternative when acquiring weapon systems from a foreign country.

Peru currently needs a broad understanding of the LCC concept. Therefore, we have avoided indulgence into detailed methodology of any acquisition technique and have focused on a theoretical study and life cycle cost approach as one acquisition technique.

B. WEAPON SYSTEMS ACQUISITION STRATEGY

Acquisition is the means of acquiring, by contract and with appropriate funds, supplies (including construction) by and for the use of the Government through purchase, lease, or barter, whether the supplies or services already exists or must be created, developed, demonstrated, and evaluated. Acquisition begins at the point when you establish agency needs, and includes solicitation and selection of sources, award of contracts, contract financing, contract performance, contract administration, and those technical and management functions directly related to the process of fulfilling agency needs by contract [Ref. 26].

Small countries normally cannot satisfy all their military needs through internal manufacturing due to a lack of domestic resources. Rarely can you find the required combination of capital, raw materials, advanced technology, and skilled manpower needed for the establishment and operation of defense-oriented industries in small countries [Ref. 27].

You can divide the acquisition strategy of a weapon system as follows:

1. Self-production
2. Co-production.
3. Direct purchase.

4. Cooperative production.

5. Military aid.

6. Mixed type.

Self-production includes developing and producing a new system, and copying or modifiging an existing system. Co-production includes technology import, license, royalty, and hardware import. Direct purchase includes purchase route. Cooperative production involves joint production, joint venture, and multi-national industry. Military aid includes grant-aid and foreign military sale (FMS). In developing countries, with less sophisticated industry and economic power, self-production may not be the best alternative.

What is the best strategy? It depends on the country and its needs. With an imminent threat and time constraint that precludes self-production, direct purchase may the best way. Co-production may be a better strategy if limited technology makes it difficult to produce high-level systems. Sometimes, allied nations undertake joint production to improve economic benefits, and strengthen the allied relationships.

Self-production of a weapons system appears to be the ultimate goal for Peru's self-defense endeavor, even if it involves disadvantages such as increased R&D and production cost, time, and a higher probability of failure during R&D.

Yet self-production has advantages, such as technical-economic effects to the other industries, enhancement of the people's morale, and inspiration of self-defense spirit.

Peru directs its FMS purchases at fulfilling one or more of these intended goals: modernization of forces, self-sufficiency, the growth of advanced technology, and security. The goal of obtaining advanced technology relates to the desire for self-sufficiency. Peru knows that it cannot produce highly sophisticated weapon systems without an inflow of technology from the developed nations. As their demand for sophisticated weaponry grows, Peru followed the lead of other nations and purchased the most advanced weapons available.

However, beyond simply purchasing these systems, and in order to improve the technical production base, the Peruvians see that co-production is an important method of transferring technology and technical capability. The level of technology transfer is an absolutely essential determent for dictating the rate and complexity of Peruvian technological advancement in the aircraft industry. Clearly, obtaining advanced technology is crucial to the Peru if they are to develop the capability for producing sophisticated weaponry. This capability will allow them to achieve the goal of self-sufficiency. It will also strengthen the Peruvian economy by reducing the monetary outflow from purchasing weapons abroad and by increasing the monetary inflow through arms sales to Third World nations.

Finally, the arms that Peru purchases must fulfill a defense need. This is the fourth, and perhaps most important goal; that of national security. Clearly, the nation buys weapons in order to deter the threat facing the nation. You must recognize that insuring the national security is the primary motivation behind Peru's purchases of weapon systems.

C. THE CONCEPT OF LIFE CYCLE COST

One of the most important weapon system acquisition concepts to emerge in recent years is that of Life Cycle Cost (LCC). National leadership and Department of Defense (DOD) top management recognize that the cost of acquiring and supporting weapon systems is far too high. In previous years, systems were (and still usually are) procured on the basis of best technical performance and lowest acquisition cost. The LCC concept, on the other hand, dictates that the Services define their minimum acceptable requirements and then procure the system that will meet those minimum requirements at the lowest cost for the entire life of the system [Ref. 28].

Air Force Regulation 800-11 defines a life cycle cost as follows:

> "The total cost of an item or system over its full life. It includes the cost of development, acquisition, ownership (operation, maintenance, support, etc.) and, where applicable, disposal."

Acquisition cost includes the cost of research, development, test and evaluation (RDT&E), production or procurement of the end item; and the initial investments

required to establish a product support capability such as support equipment, initial spares, technical data, facilities, and training, among others. Ownership cost includes the cost of operation, maintenance, and follow-on logistics support system.

The terms "ownership cost" and "operating and support" (O&S) cost are synonymous. Thus, the four major cost categories included in the LCC estimate are research and development, production, operating and support, and disposal.

In the context of this chapter, life cycle costs are the total cost to the Peruvian Government for the acquisition and ownership of a particular system. Therefore, life cycle costing is a technique that supports the analytical study of a system's LCC. This takes into consideration the total costs of ownership, that is, all operating and support costs, as well as the acquisition prices, for the useful life of the system. LCC also is an acquisition or procurement technique that considers operating, maintenance and other costs of ownership, as well as acquisition price, in the award of contracts for hardware and related support.

Using LCC enables you to consider all costs of ownership, as well as those development and acquisition costs which are closest on the fiscal horizon, during the acquisition process. By considering all costs throughout the system life cycle, you can more readily see the total economic advantages and disadvantages of various design and development options [Ref. 28].

The use of LCC assumes that you will make your decision concerning the acquisition of a weapon system by evaluating total LCC. Then, you will choose

the system from among those providing a given level of effectiveness and having the lowest LCC. The validity of this assumption rests on a presentation of the acceptability of a temporal transfer of the budget between years, without regard to the probability of war, or assuming that war is so far in the future that the decision can focus on peacetime costs only.

1. An Historical Profile of LCC

The DOD acquisition process has used the idea of life cycle costing for over 25 years. DOD polices, directives, the Armed Services Procurement Act and the Defense Acquisition Regulation mandate its use. The Armed Services Procurement Act of 1947 states:

> "Award shall be made . . . to the responsible bidder whose bid . . . will be most advantageous to the United States, price and other factors considered [Ref. 29]".

The supporting report of the Senate Committee on the Armed Services confirmed that "other factors" included consideration of "ultimate cost." Nevertheless, award of contracts on the basis of acquisition price alone continues to be the predominant practice by an overwhelming proportion. Furthermore, the Armed Services Procurement Regulation (ASPR) states, "It is the policy of the Department to procure supplies from responsible sources at fair and reasonable prices calculated to result in the lowest ultimate overall cost to the Government [Ref. 30]". Defense Procurement Circular Nº 115, dated 24 September 1973,

added a section on life cycle costing to the ASPR (section 1-335). This section states:

> "Since the cost of operating and supporting the system or equipment for its useful life is substantial and, in many cases greater than the acquisition cost, it is essential that such costs be considered in development and acquisition decisions in order that proper consideration can be given to those systems or equipments that will result in the lowest life cycle cost to the government".

Although this regulation mandates LCC consideration, we seldom use the LCC technique to its full potential as a program management tool.

During the mid-1960's, the rapidly increasing technical complexity of defense acquisitions led to steadily rising unit procurement costs. These increases in costs, along with a general economic inflationary trend, resulted in vigorous efforts to constrain the cost growth then associated with military systems acquisition.

The increased emphasis on cost during the 1960's led to techniques that included cost as a major system evaluation criterion. Prior to this time, the two criteria predominantly used for defense systems evaluation and selection were performance and schedule. Managers used these criteria to evaluate a system on its ability to combat a threat (performance) and its ability to meet development and deployment time considerations for that threat (schedule).

In January 1961 Robert McNamara became Secretary of Defense. During his first year in office, he decided to centralize the authority and planning for the defense establishment at the level of the Office of the Secretary of Defense and to decentralize operations. He acted in order to improve the defense planning process by instituting the following:

1. Planning-Programming-Budgeting System (PPBS)
2. Five-Year Defense Plan (FYDP) and
3. Use of system cost-effectiveness analysis in the defense decision-making process.

The initial concepts developed during the 1960's to control military acquisition cost grew from Secretary of Defense McNamara's systems analysis efforts. The first control technique which ensued was that of cost-effectiveness analysis. The DOD used the first technique to systematically quantify both the costs and benefits of decision alternatives. The analysis was called "cost/benefit" analysis if identifiable benefits were measured in dollar values. Alternatively, if benefits could not be reduced to quantifitable dollar values, the analysis was called a "cost-effectiveness" analysis.

The second technique that evolved from the increased interest in cost control was Life Cycle Cost analysis. This concept emerged conceptually during the mid-1960s. The innovative concept of LCC was that you would consider ownership cost with acquisition and development cost in the weapon system selection decision. The identification of the ownership cost was of particular importance

when you consider that in many weapon systems the "ownership" costs over the life cycle far exceeded the initial acquisition costs of the system itself.

Since then, two other techniques have evolved. The first, Design-to-Unit Production Cost, emphasizes the importance of designing systems to minimize their unit production cost. Unfortunately, this technique focuses on control of acquisition costs, perhaps without regard to the future costs of ownership of the weapons system.

The second technique, Design-to-Cost (DTC), acknowledges the importance of ownership costs and the impact that design decisions played on these future costs. DTC is a concept of management where you establish stringent cost objectives during system development. You then strive to meet these objectives by practical trade-offs between development schedule, performance, operational capability and cost itself. In DTC, cost is a design parameter you continually address. It is an inherent part of system production and development [Ref. 31].

DTC focuses on all acquisition and O&S costs of the LCC equation except R&D. You express an acquisition DTC goal in the form of fly-away, roll-away, sail-away costs. You can express DTC O&S goals in dollars or other measurable factors, such as reliability, maintainability, and personnel, that are design-controllable, significantly affect O&S costs, and measurable during test and evaluation [Ref. 32].

Only Life Cycle Cost analyses provide for estimation and control of all three phases of a system's cost-development, investment, and operations and support. Use of LCC techniques in an acquisition can help avoid suboptimal emphasis on production costs at the expense of future operating costs. However, implementation of these techniques has been slow and the use of LCC as a design parameter has met with varying degrees of success [Ref. 33].

2. Uses of Life Cycle Cost Information

The Life Cycle Cost estimate has many and varied uses. Seldom M. Rovert [Ref. 34], lists six primary uses of LCC:

- Long range planning
- Comparison of competing programs
- Comparison of logistics concepts
- Decisions about the replacement of aging equipment
- Control over an ongoing program
- Selection among competing contractors

In addition, Thomas E. May [Ref. 35], lists the following uses of LCC estimates:

- Support of budget estimates
- Design-to Cost (DTC) program
- Management reviews

These uses equate to one common purpose: LCC supplies information to assist in the decision process. Thus, life cycle costing is a continuous

management process. It ensures that new acquisitions meet operational needs at the lowest life cycle cost [Ref. 28: p. 1].

3. Weapon System Life Cycle Stages and Costs

Benjamin Blanchard [Ref. 36], gives the concept of the life cycle as follows:

> "A system, to be useful, must satisfy a need. However, designing a system to just meet the need is not usually sufficient. With few exceptions, the system must be able to continue to meet the need over a specific period of time in order to justify the investment in time, money, and effort. Thus one must consider a system in a dynamic sense."

Specifically, for a weapon system, the life cycle is the period which begins with threat analysis and the need for the weapon system, and ends with its disposition. Figure 1 graphically portrays the relationship of LCC to the weapon system life cycle. The dotted lines approximate the periods when you make cost influencing decisions.

1. Conceptual

This phase includes investigations into weapon system design feasibility and planning by service, government, and contractor personnel. Important outputs from conceptual studies are initial estimates of weapon system acquisition and operational costs.

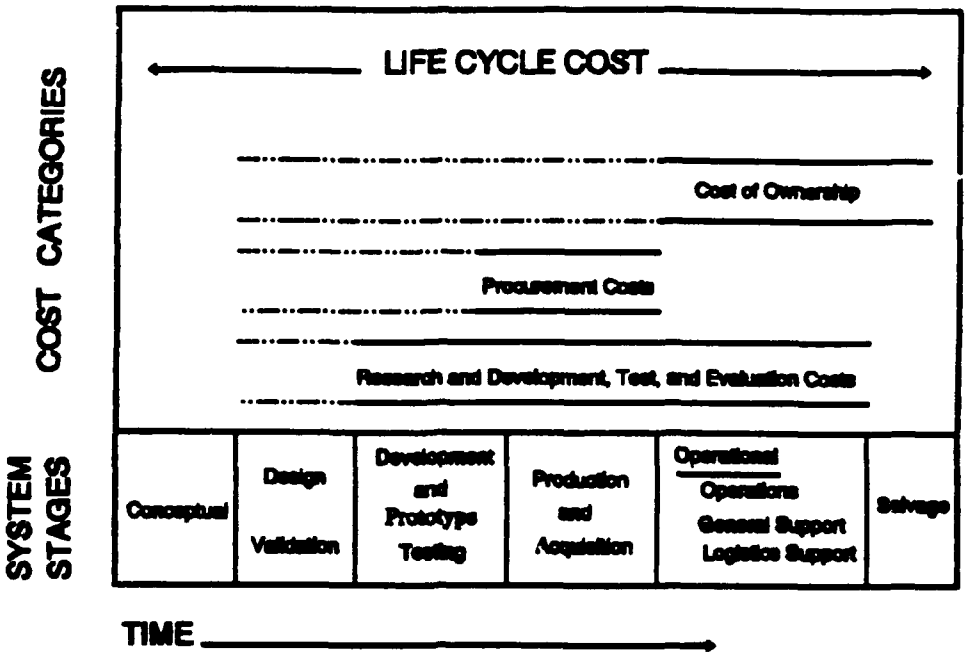

Figure 1: Weapon System Life Stages and Cost

2. Design Validation

In this stage you specify the desired performance and physical parameters of the weapon system and additional research and development and preliminary cost estimates. You prepare a request for proposal (RFP) and distribute it to potential contractors. You process the responses to the RFP and evaluate the individual proposals. Improvement products from this stage are the prototype designs, and fabrication and testing of the basic design.

3. Development and prototype testing

You set the basis for full scale production during this phase. You construct, test, and evaluate a number of prototypes. Additional R&D for product improvement takes place. Pursuant to successful testing, you give the go-ahead for production for the preferred prototype design. Prototype testing can include several competing designs from two or more contractors.

4. Production and acquisition

During this stage, you fabricate and test one or more of the production-configuration systems of the selected design. You create a contract, or series of contracts, for a production of the required quantities. You carry-out any additional R&D for necessary system and component improvement and make estimates for initial spares requirements.

5. Operational

In this stage, you use and maintain the weapon system for its primary mission. You also use, purchase, and maintain spare parts. This stage generally lasts 10 years or more for major weapon systems.

6. Disposal or Salvage

This phase entails the removal, disposal or conversion through modifications, of the system to another mission function.

Given is sequence of phases, we can associate with one or more stages various military costs for: research and development, production or procurement, ownership, and salvage. The summations of these costs are the life-cycle costs for

the weapon system. The following paragraphs list definitions for each category [Ref. 35: pp. 2].

1) Research and Development is those costs associated with the research, hardware and software. More specifically, it includes the cost for feasibility studies, simulation or modeling, engineering design, development, fabrication, assembly and test of prototype hardware, initial system evaluation, associated documentation, and test of software.

2) Production is those costs associated with production, initial support equipment, training, technical and management data, initial spares and repair parts, plus many other items required to introduce a new system to the field.

3) Operating and Support is the cost of personnel, material and facilities, of both a direct and indirect nature, required to operate maintain and support the hardware and software of the system.

4) Disposal is the cost associated with demilitarizing or otherwise disposing of a system at the end of its useful life, minus any salvage value. This category is seldom estimated in most analysis. Often this value is very small in comparison to the other categories.

4. *Relationship of development cost in system life-cycle cost*

In practice, life cycle cost estimates can indicate the size and relative amount of resources required for the development, production and operational phases of

a system. The greatest value from life cycle costing will result when it is used early in a system life cycle for the basic program decisions on requirements and designs. Figure 2 graphically shows this. Over 70% of the life cycle costs of the system early are determined in the life cycle and prior to the time the Secretary of Defense approves the start of the Demonstration and Validation phase.

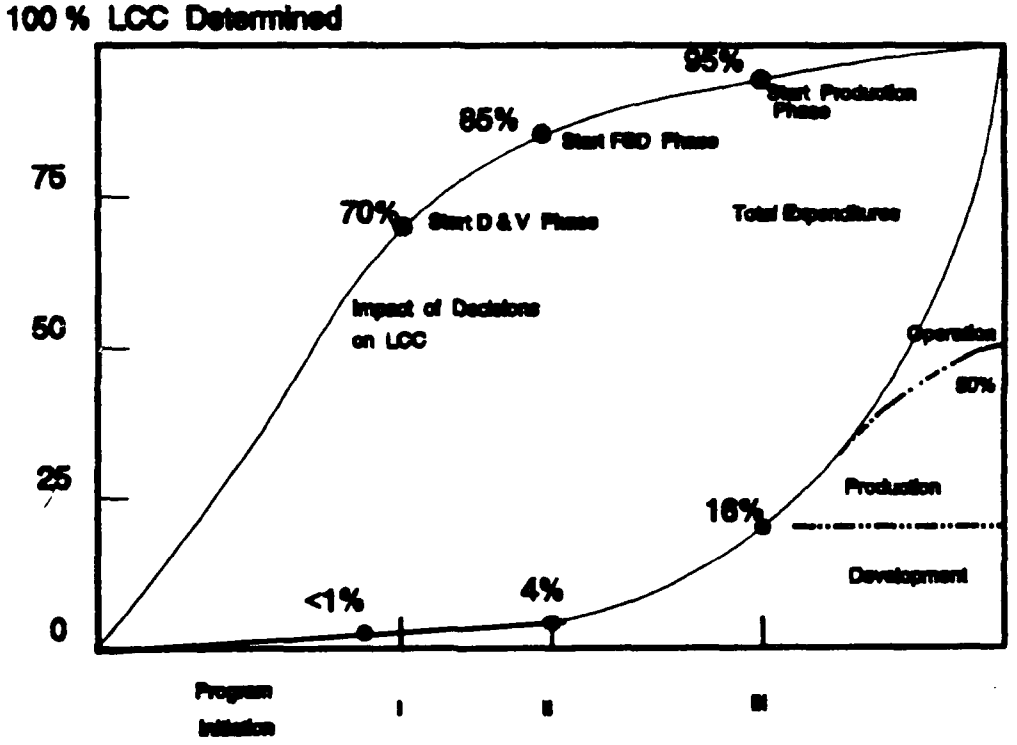

Figure 2: System Life Cycle, DSARC Milestone

These decisions would have been made on the basis of conceptual design studies and the statement of required operational capability provided in the operating command. Key cost drivers include performance, operational environment, reliability, logistics concept, the extent of use of Military

Specifications and Military Standards and the procurement or competitive approach during the acquisition process.

This process freezes roughly 85% of the LCC before the Full-Scale Development phase begins, when you have expended only a small percentage of the total system cost. Also, by its end, Full Scale Development determines around 95 percent of the LCC. A little more money spent in the early stages of the program can save a great deal of money over the life the system [Ref. 32: p. 1-8]. Figure 2 emphasizes the importance of fully considering life cycle costs early in the life cycle.

D. THE KEY FACTORS AFFECTING LIFE CYCLE COST

This section identifies factors that affect LCC. Concentration on these factors early in the system's acquisition process will provide cost reductions or the rationale for necessary tradeoffs.

1. Performance requirements

For years, the achievement of higher performance, regardless of costs, guided weapon system development. Failure to consider cost permitted essentially unrestrained performance specifications. This, in turn, impacted both acquisition and support costs tremendously. A recent [Ref. 37] Boeing Aerospace study noted, for example, that an increase in the design Mach number of a transport aircraft from .5 to .8 resulted in corresponding increase in maintenance man hours per flying hour from 12 to 19. Similarly, an increase in the design Mach number of bomber aircraft from .8 to 2.0 generated a

maintenance man hour per flying hour increase from 26 to 55, while a like increase in the design Mach number for fighter/attack aircraft from 1.9 to 3.5 increased the required maintenance man-hours per flying hour from 20 to 250. The cited examples illustrate the impact of an increase in just one performance requirement on the support cost of a weapon system. Add to that requirements for increased accuracy, maneuverability, time to climb, reaction time, among others, and life cycle costs soon begin to go out of sight. The need to challenge such requirements at the very outset of system development clearly is evident. You must do serious cost tradeoff analyses to properly assess the affordability of increased performance requirements.

2. Reliability

Because of its impact on both weapon system effectiveness and life-cycle costing, reliability plays a key role in trade offs between these two parameters. While effectiveness increases directly with reliability, the life-cycle cost/ reliability relationship is not so simple. Figure 3 illustrates the classical relationship between these latter two variables where reliability in this case is quantified in terms of Mean Time Between Failure (MTBF) [Ref. 38].

As the figure illustrates, while MTBF drives down support costs, it achieves this with increased acquisition costs. By definition, the life cycle cost curve is the sum of the acquisition and support cost curves. Examination of this curve reveals that you achieve the optimal life-cycle cost at the MTBF corresponding to the low point on the LCC curve. Decreasing or increasing MTBF from that point will

drive up life-cycle costs. While this classical relationship may or may not be applicable to individual weapon systems, it does illustrate a common relationship.

An additional relationship results from the so-called "force multiplying effect [Ref. 39]". For example, if you can increase the reliability of a particular weapon system by 25% through improved design practices, this improved reliability produces the same operational effects as having a 25% increase in the number of those weapon systems available to accomplish their mission. Yet, you incur little if any additional support cost. The alternative is to buy more systems. System-wide acquisition costs, then, decrease with the reduction in the number of required buys.

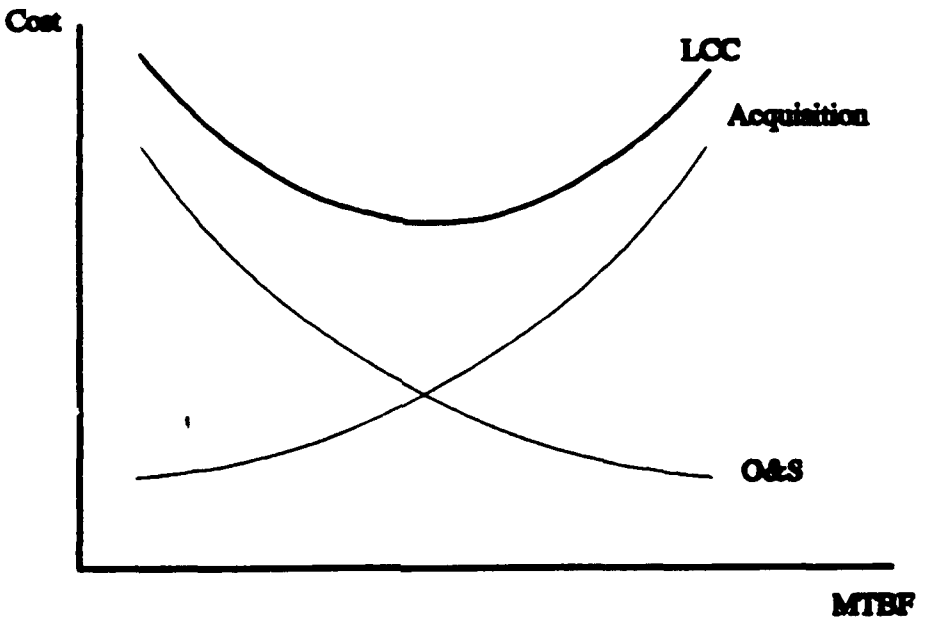

Figure 3: LCC / Reliability Relationship

3. Maintainability

Maintainability impacts life-cycle costing in two ways. First its impact on the availability of a weapon system to perform the assigned mission has the same force multiplying effect as reliability. Perhaps its greatest impact, however, is in the area of manpower costs. The maintainability of a weapon system as determined by its complexity, access to equipment, trade off between field and depot level maintenance, among others, determines the number and skill levels of personnel required to operate and maintain it. These factors also impact the size and structure of training programs needed to provide manpower to support the system.

You must address maintainability early in the design of the system. Designs which provide easy equipment access, abundant diagnostic information, and reduced complexity will yield substantial support cost dividends.

4. Complexity

While the complexity of a system may seem directly tied to performance requirements, a thoughtful analysis reveals that the connection is less direct. Simplicity of design normally produces reduced acquisition and support costs.

In attempting to quantify complexity the Boeing study cited earlier concluded that complexity was a function of the number of parts in the system. Fewer parts generated reduced development costs, reduced production costs, and reduced operating costs [Ref. 37: p. 4]. Fewer parts require fewer production steps, tools, spare inventories, and drawings. Hence, lower costs result.

5. Standardization

The idea of standardization is related directly to the idea of complexity. Standardization within the system allows for less unique parts and/or less one-of-a-kind subsystems. In turn, this precipitates less costs for the reason stated above. Standardization of subsystems also permits the centralization of depot repair facilities with attendant reductions in support costs.

The development of the F-16 provides an example of dividends resulting from attention to standardization principles. Some 254 components on the F-16 are identical to those on the other aircraft while an additional 78 are modifications of such components. Across the aircraft itself, such features as ambidextrous horizontal tail surfaces and flaperons, 80% commonality of right and left landing gear parts, and use of a single electro-hydraulic servo in five different locations in the flaperon system further illustrate the results obtainable from a standardization conscious design effort [Ref. 37: p. 16].

6. Technology

Technology can serve as master or servant in the development of a new weapon system. In the latter role, introduction of technology innovations into the design can reduce both acquisition and support costs.

Technology can become a harsh master, however, when you introduce new, untried technologies to meet increased performance requirements, or when the designer falls prey to the "because we can, we must" syndrome (technological imperative) [Ref. 40]. In these roles, the new technologies first push up

acquisition costs, then return later with hidden support costs that reveal themselves only with age and use. Effective defenses against such cost increasing tendencies include extensive, realistic testing to provide a broader understanding of the new technology and the disciplined tailoring of the technology to realistic requirements.

E. THE ACQUISITION PROCESS PHASES

This section provides a basic knowledge of the acquisition process and the ways life cycle costing may be used throughout the acquisition process of a weapon system. The program manager may use life cycle cost concepts throughout the acquisition process for a major program.

The United States DOD Directive 5000.1 defines four distinct phases of the acquisition process: concept exploration, demonstration and validation, full scale development, and the production and deployment phase. The four phases are separated by decision milestones.

It is not necessary for every system to move through each phase one by one, nor is it unusual for a system development to begin at any of the phases prior to or at the production and deployment phase [Ref. 32: p. 1-18].

The starting point for a major system originates in many sources. The need may arise from a perceived or changed threat, from obsolescence of existing systems, or from a technological or cost reduction opportunity. Ideally, the mission need would originate from a situational summary, a document which

discusses weaknesses of an operational plan as experienced during trial maneuvers or exercises of a Unified or Specified Command.

1. Concept Exploration Phase

The first phase for a major system is the concept exploration phase. During this phase, you assign the program manager and consider several alternatives to do the mission. At the end of this phase, Milestone I, you make a decision to select the alternative or to request further development in the ensuing phase. You need to solicit alternative concepts for achieving the mission need from R&D laboratories, universities, or industry [Ref. 32: p. 1-14]. This phase is critical so far as determining the system's future cost. As pointed out in Chapter III - Section C, the activity during this phase determines over 70% of the life cycle costs of a system. Therefore, making the right decisions during the conceptual exploration phase is crucial [Ref. 41].

A small amount of money spent over a short period of time during this phase has a significant effect on the system's performance and cost for the rest of its life cycle. Wrong decisions create problems. Solutions to those problems later in the program life cycle require much larger expenditures of resources and time.

This phase involves trade off studies of competing concepts capable of satisfying operational needs. Of necessity, these concepts start out on a broad scale and then become more narrowed and more explicit as the concept exploration phase progresses. Premature introduction of operating and support details may have a negative effect by closing out promising alternatives [Ref. 42].

During this phase, you should generalize life cycle cost models and concentrate on the types of support alternatives and functional environments the actual operational system will see. They should provide an analytical framework for the conceptual studies and support key tradeoff decisions. You should build the program model to identify the relative life cycle cost impacts of system alternatives. This should identify only those major characteristics that drive the major system costs. Detailed cost information has little utility during this phase [Ref. 43].

2. Demonstration and Validation (D&V) Phase

This is a key phase as it verifies the ability of the design to meet mission needs. During this phase, you select alternatives from the concept exploration phase that you want to demonstrate, either by analysis or actual prototype design. This verifies the capability, availability, and credibility of the critical aspects of the system design. Prior to the next phase, decisions are made to select the best alternative for further development [Ref. 32: p. 1-14].

The D&V phase is pivotal in the acquisition process. Dollar expenditures during this phase represent only about 3% of the system LCC. However, since expenditures in the succeeding phases are largely determined by the decisions made in the D&V phase, the cost/risk/performance tradeoffs made during this phase will have a marked impact on LCC. [Ref. 32: p. 3-30].

Life cycle costing activities during this phase become more detailed. The Integrated Logistics Support (ILS) plan forms a convenient reference for operating

and support concepts. Logistics support constitutes a principal design parameter with the magnitude, scope, and level of this effort by the contractor consistent with other D&V phase activities [Ref. 34: p. 4].

During this phase, you must provide the contractor with proposed maintenance plans, flight profiles, basing plans, number of aircraft at each base, and logistics data which can be used for LCC tradeoffs [Ref. 43: p. 4]. Based on the extent contractors can identify data needed to construct a life cycle cost model, the life cycle cost model begins to take form. Both the program office and contractors use the model as a management tool.

At this point in the program, life cycle costing should become at least a subconscious influence if not a conscious influence on all program activities. The key challenge to the use of LCC model during this phase of a program's development is to relate specific design tradeoffs to resultant O&S costs. The data base for the LCC model represents the best available planning information from similar systems in the inventory. You may use the model in any of the trade offs. A typical one might be determining the level of design in an electronic component which will be removable and replaceable at base level. This decision is intimately related with the optimum repair level analysis, reliability and maintainability data, environmental data and logistics support data and is all integrated by the life cycle cost model [Ref. 44].

As this phase proceeds, the program office and contractors identify deficiencies in the LCC model in terms of both structures and the adequacy of its data. Thus, the LCC model evolves as the system evolves.

3. Full-Scale Development Phase

Full-Scale development includes three subphases for completing the design and verifying its effectiveness through testing. The sub-phases are detailed engineering, prototyping and a pilot production sub-phase. This phase is important for several reasons. During this phase, you select a production contractor, and the second source if high volume production is planned. Prior to selecting a second source, you must develop the strategy for a second source as a requirement. You obtain the second source through previous contracting. In this phase, testing culminates with the signing of Approval for Full Production (AFP), prior to proceeding to the next phase [Ref. 32: p. 3-36].

At the conclusion of full scale development, the program should be ready for production of operational hardware. This requires the full-scale development phase to resolve all technical as well as cost risks remaining in the program. Early in this phase, the LCC model will have become sufficiently mature to serve as an aid in selecting contractor sources.

If life cycle costing is a source selection factor, the Government should advise the bidders of the basis for the Government's evaluation. In addition, for both completeness and fairness, the Government should provide contractors specific operational scenarios that form the basis for the cost model. These

scenarios should include deployments, operational concepts, maintenance and resupply planning, assumptions and constraints, etc. Government reliance on contractors life cycle cost estimates should probably ignore those cost factors provided or imposed by the Government which are common to all bidders. These may include Government furnished subsystems, fuel, and weapons, among others [Ref. 45].

A means of motivating the contractor to develop a system with the lowest reasonable life cycle cost is to include contractual provisions for award fees based on demonstrated improvements in failure rates and reliability during prototype testing.

Both the Government and the contractors are still dealing with uncertainty about future O&S costs. Each party must recognize these uncertainties. The program manager would continue to use the LCC model during this phase. The model would be even more detailed than in earlier phases and include award fee and warranty options. Its utility in day-to-day decision making expands as the program progresses. Both the Government and the contractor can exercise the model at the subsystem or major assembly level to determine the relative effects of design alternatives on life cycle costs.

But a model is just a model. It only represents the real world. Because of uncertainty and lack of detail, it is not the real world. Therefore, the Government needs some means to verify, before the production phase, those performance characteristics of the system that make up the largest share of the operating and

support costs. One method of determining these characteristics of the system is through testing pre-production prototypes. A key contribution of this early testing to improving cost estimates is the indication of relative sensitivity of life cycle costs to various cost factors. For instance, the sensitivity of tradeoffs between the number of spares in the supply pipe-line and the system or subsystem mean time to repair can be estimated in terms of life cycle costs [Ref. 45: p. 22].

4. Production and Deployment Phase

This is the most costly of all the phases. During the production and deployment phase, the system is assembled in accordance with previously developed documentation and put into use by the particular Service. For high-volume production, you normally use a second source, in accordance with the previously designed strategy. For low volume production, where the systems are highly sophisticated, you may want to second source subsystems or components [Ref. 32: pp. 1-16].

You will already have made decisions determinig 95% of the life cycle costs [Ref. 41: p. 36]. You may or may not have achieved the basic objective of life cycle costing, that of reducing the cost of ownership of weapon systems. Yet even at this point in the life of a program, the life cycle cost model continues to have utility. The primary contractual activity during this phase of the program is the award of a production contract. Life cycle cost models may play a major role in the procurement process. As a hedge against uncertainty, one possibility is for

the Government to include a provision in the production contract to adjust the award fees based on whether the contractor exceeds or fails to meet the life cycle cost criteria which formed a base for the contract award. The philosophy behind such a provision is that the contractor should share in both the cost risks and the rewards associated with the O&S costs of the equipment they provide [Ref. 46].

An additional way to reduce risk for the Government in production contracts is to include provisions for various types of warranties or contractor guarantees for field reliability and performance. The Government would then share any savings with the contractor or hold him responsible for any shortfalls in system performance [Ref. 47].

The common purpose of each of these possible contract provisions is to provide a means to motivate the contractors to do a good job in the beginning in terms of life cycle costs and, if they fail, have them share or even fully absorb the additional costs.

As a result of the testing of initial production articles, actual cost data can be inserted into the life cycle cost model and replace the predicted data that had been used up to that point in time. Of particular importance is the base level O&S costs which form the foundation for future use of the LCC model.

An initial use of the LCC model during the deployment phase will be to verify the adequacy of the maintenance data collection system used for that particular weapon system. During this phase, the LCC model is updated and

refined to use as a management tool for key logistic support and modification decisions. Thus, the LCC cost model appears to have utility throughout the life cycle of the system [Ref. 31: p. 5].

The potential utility of life cycle costing extends throughout the concept exploration, demonstration and validation, full-scale development, and production and deployment phases of the system [Ref. 31: p. 6]. The life cycle cost model is constantly refined and updated. Hopefully, it will have served its primary purpose as a management tool for reducing the total cost of ownership of a system and reducing some of the uncertainty inherent in the decision making process during system acquisition.

F. METHODOLOGY FOR LIFE CYCLE COST ANALYSIS

This section presents a general methodology that you should follow in estimating life cycle costs in any cost analysis of weapon system acquisition. You can view the methodology as a flow chart that depicts the organization required to produce an LCC model. The steps in the methodology are:

1. State study objectives
2. Define assumptions
3. Select cost elements
4. Develop cost estimating relationships
5. Collect data
6. Estimate element costs
7. Perform sensitivity analysis

8. Perform uncertainty analysis

9. Present results

These nine basic steps are not a serial process, rather they are interdependent and interactive. Most LCC analyses will include these general procedures in greater or lesser detail dependent upon analytical requirements.

Usually, you organize these life cycle costs estimates to serve as inputs, along with the results of system effectiveness analyses, to cost-effectiveness studies. They are also useful as inputs to reports containing independent costs estimates and to many other kinds of management planning efforts.

1. State analysis objectives

The first step of the methodology is to identify, formulate, or state the analysis or study which originally generated the need for the cost estimating exercise. Properly identified objectives will help to define and limit the scope of the cost analysis effort.

2. Define assumptions

The adoption of valid assumptions that underlie the estimating process in life cycle costing is critical if the exercise is to yield useful results. Assumptions are often necessary to make the abstract cost model more representative of the proposed real world, because all specific detailed inputs are not always available, particularly for "far-out" systems. The adoption of assumptions allows the analyst to set parameters around uncertainties and proceed with the analysis.

It is important that the assumption be formulated by those personnel closest to and most experienced in the areas in question – typically not the analyst himself. As an example, logistics personnel should formulate the support concept assumptions and acquisition strategies should come from the Program Manager.

Typical assumptions for systems/equipment LCC analyses are as follows.

a. Procurement quantity

b. Rate of production

c. Concept of operation

d. Logistics support concept

e. Life of the equipment/system

f. Residual value

g. Disposal costs

h. Rate of discounting

i. Sunk costs

3. Select Cost Elements

The identification of cost elements is an important step. It involves the listing of all program costs into a structure that assures that you account for all major costs, that costs are not doubled and that the cost elements are consistently and clearly defined. Cost elements for sunk cost categories need not be considered.

4. Develop Cost Estimating Relationships

You must specify the procedure for estimating each cost element in this step. The analyst can select a parametric, engineering, analogy or subjective CER for the cost model. The following chapter will briefly discuss cost estimating techniques. The availability of relevant data at the point when you are conducting the analysis will influence this step. As the acquisition process progresses, the mixture of cost estimating procedures selected for analysis will usually shift from the use of CER's to the use of actual costs.

5. Collect data

One of the greatest problems in estimating life cycle costs is the collection and validation of data. The data required for the analysis are often not available, particularly during the R&D phase. Even when data are available, they may be in a format unsuitable for the analysis at hand.

Data collection represents perhaps 90 percent of the total work effort in LCC analysis. DOD Instruction 7041.3 suggests the following data sources: established reports, opinions and judgement of experts, observation and tabulation of steps in a work process, outside organizations, and information centers.

6. Estimating Element Costs

After you have collected and validated the necessary input data, you must estimate element costs through the use of relevant CER's. You should also estimate the degree of cost uncertainty. You can express this statistically through confidence intervals or through pessimistic, most likely, or optimistic estimates.

7. Perform Sensitivity Analysis

The sensitivity analysis aids the analyst in determining uncertainty in life cycle cost estimates. The intent is to (1) determine the sensitivity of certain input parameters to the analysis results, and (2) to assess the risk and certainty associated with a given decision (i.e., the probability of making a wrong decision). In essence, the analyst needs to address the "what if" questions in an attempt to minimize the risks associated with given decisions [Ref. 48].

Generally, you perform sensitivity analysis at two different levels of estimation. The first is at the cost equation or CER level. At this level, sensitivity analysis attempts to describe the possible effects if a developed CER fails to "capture" or accurately describe that element of cost which it is attempting to estimate. The second level of sensitivity performance is on the aggregate total LCC. Here sensitivity analysis helps define the cost effects of all CER's if they interact in a manner which produces an inaccurate over-all estimate of true system cost. This sensitivity of the total estimate is important since errors in individual CER's may be additive in one direction or the other and inter-relationships may be disguised by offsetting errors.

Frequently, you use sensitivity analysis to define likely costs in the O&S area, if you make performance trade-offs. For example, "what would be the additional O&S costs incurred over a system's life if mean time between failure (MTBF) specifications were lowered by "x" amount for the equipment?". This technique is a valuable tool which informs management of the cost associated

with various alternatives and, more importantly, possible costs associated with errors in either cost estimation or the defined assumptions [Ref. 48: p. 98].

8. **Perform Uncertainty Analysis**

In accomplishing a life cycle cost analysis, you can introduce risk and uncertainty in many areas. The more that this occurs, the less valid the analysis becomes. Hence, although the various aspects of risk and uncertainty can not be eliminated altogether, it is the intent to minimize them to the greatest extent possible [Ref. 48: pp. 99-100]. Uncertainty analysis is especially important with large acquisition cost elements, such as unit production, costs, and to significant O&S cost contributors such as personnel and depot maintenance. In the very early stages of product development (when uncertainty is greatest) it should at least be possible to bound a most likely estimate with a high and low variant. The high and low estimates should preferably reflect actual cost experience with other systems or equipment or be based on the outcome of certain events or policy decisions rather than being arbitrary percentage adjustments to the original estimates. As the effort proceeds further into the acquisition phases, more through uncertainty analysis should be possible. Description of uncertainty as a probability distribution (often subjectively derived) is a widely and effectively used practice. In summary, a LCC is simply incomplete if no attention is paid to uncertainty analysis [Ref. 49].

9. Present the LCC Estimate

A properly completed LCC analysis will identify those costs associated with the unique situation defined by the objectives of the study. It is a result highly dependent upon the specific assumptions associated with those stated objectives. Therefore, it is imperative that the cost estimates always be closely associated with the study from which they are drawn.

The actual format of an analysis can take many shapes, dependent upon its intended recipient, but should as a minimum, describe individual cost elements and cost categories by both annual and total costs [Ref. 50].

Additionally, you should present the cost estimates in an escalated, de-escalated and constant year dollar format. The overlying cost analysis instructions specify the overall format of presentation.

IV. ECONOMIC ANALYSIS

A. INTRODUCTION

This study does not evaluate the economic analysis process nor the requirements of learning the process. As Lang [Ref. 51] showed, the economic analysis process is complex and requires an orderly approach. Learning how to develop an adequate economic analysis report requires a text dedicated to the topic and teachers with specialized skills. Instead, this study points out that Peruvians responsible for the acquisitions of weapon systems could use economic analysis to mitigate the drain that the acquisition of weapon system poses to their economy.

Due to their limited economic resources, when Third World nations develop even modest military forces, they do so at the expense of other, often needed, social programs. While Direct Military Sales represent the greatest direct drain to a limited economy, the use of FMS credits from the US and USSR creates secondary economic burdens. Because the acquisition of weaponry requires scarce time and resources, the leaders of the Third World must understand the available alternatives, their costs, and their benefits. Economic analysis is a tool that evaluates and compares alternatives.

B. THE ECONOMIC ANALYSIS REPORT

The final product of an economic analysis is the economic analysis report. This report is essentially a decision paper that supports a buy, make or forego recommendation. As such, you must ensure that the report is a high quality product, written and presented with the utmost care. As you may present your findings and recommendations to several levels of management within your organization, you may have to write your report with varying amounts of detail in its various parts. Appendix C is an example of a complete economic report. Appendix D establishes a routine to perform economic analysis. A Peruvian Action Officer could use those Appendix as the foundation of his economic report.

The three main parts of the economic report are:

1. Executive Summary

You place the executive summary at the beginning of your economic analysis report. The executive summary tells upper management of the coverage of your study, major costs and benefits you noted, and your recommendations. This part of your report is particularly important owing to the time constraints of management. Therefore, your summary must be succinct and present the salient findings of your work.

2. Main Body of the Report

Here, you discuss all relevant findings, recommendations, benefits and special observations or considerations. If applicable, you suggest steps for implementation.

3. Appendices

You use appendices after your report to present lengthy, detailed data to support your findings and recommendations.

C. VISUAL AIDS FOR PRESENTING DATA

Use visual aids to show data. Visual presentations such as charts, graphs and figures improve your report's readability. Visual aids help others comprehend the impact of the ratios and relationships you present. Charts, graphs and figures should be clear, brief, and specifically relate to your text. According to Weiss, every new idea should have its own illustration and that illustration should be *redundant* with the text, not a supplement to the text [Ref. 52].

D. SUGGESTED OUTLINE FOR YOUR REPORT

According to Lang, there is no set format for preparing an economic analysis report [Ref.51: Appendix E, p. A-2]. You must tailor each report to meet the complexity and the economic value of the proposed acquisition. Yet, as you base the economic analysis upon well founded economic principles, similarity of ideas

and format will exist among various reports. Appendix A is a suggested outline for the economic analysis report.

E. ECONOMIC ANALYSIS REVIEW CHECK LIST

The Economic Analysis Review Check List is a tool you use to ensure that you develop a complete economic analysis report. While the check list closely follows the suggested format, using the check list ensures that you fully develop each part of the report and ensures that you are consistent with the level of detail you provide.

Like the economic analysis report, the check list is a recommended tool to use to develop an economic analysis report, but it is not a required tool. Therefore, should a Peruvian Action Officer find that he cannot incorporate an item on the list into his report, given a rational basis for deleting the item, he may do so. Appendix B is a recommended economic analysis review check list.

V. CONCLUSIONS AND RECOMMENDATIONS

A. FOREIGN MILITARY SALES

Since the formalization of the Foreign Military Sales (FMS) program in 1949, the US spent more than 7.5 trillion dollars on national defense [Ref. 53]. While FMS is a small part of the Federal Budget, the ability for Congress to push FMS into particular areas (pork barrelling) and augment existing weapons purchases (economies of scale) promotes key Congressional support for FMS. Because of the perceived economic impact of FMS, the Bush Administration fully supports the program.

In a move supposedly benefitting the economies of the Third World, President Bush requested all the fiscal year 1990 FMS funds as grants. Regretfully, this does not address the economic drain that direct commercial sales will cause in the Third World. Nor will this rectify the continued, brutal assault against basic human rights. Unless the US sets up a new way of thinking concerning FMS, we shall continue to see a Third World arms race. We shall continue to see the wholesale abuse of human rights. And we may see the US forces in the Third World.

B. SOVIET UNION ARMS TRADING

Arms trade with the Third World is very important to the Soviet Union, Arms trading yields a source of desperately needed hard currency. Arms trading

allows the Soviets to exert "spare parts diplomacy" upon their client states. Finally and possibly more importantly, arms trading allows the Soviets to have access to strategic regions.

There are indications that the Soviets have incorporated much Western technology in Soviet weaponry, from look-down, shoot-down radars to missile technology. The Soviet Union benefits twice from acquired western technology. First, by the initial assimilation of technology and the advantages of using the systems that incorporate that technology. Second, by the advantages associated with Third World arms trade as stated above.

On the other hand, the Third World partner like India, also benefits from the same technology in that it not only uses the product but it also can use the Western technology in its own defense industry via license or eventual indigenous production.

Like trade with the West, economic and political gain motivates the Soviet Union to expand trade with the Third World. In Soviet terms, they see opportunities for expanding mutually beneficial economic cooperation with the newly free countries of the old colonial and neocolonial empires. These opportunities are attractive, considering the developing countries' need for independence and the economic growth of the Socialist countries. In the Soviet view, through this beneficial cooperation, these newly freed countries that are developing their society, political parties, and economies will, "welcome with understanding the policy pursued by the Soviet Union and the Socialist's

community as a whole, and will actively promote friendship and cooperation with them [Ref. 54]".

Historically, the Soviets professed that the Third World countries were their natural allies against the neocolonial United States. Moscow placed special emphasis on the extension of their economical power and influence in the Third World. Traditionally, they saw the inevitable collapse of the neocolonial system as a prelude to the collapse of capitalism [Ref. 54: p. 239].

While the Soviets under the leadership of Gorbachev have toned down their rhetoric, they have not spurned their socialist system nor their aim to spread socialism. Despite a troubled economy at home, the Soviets are expanding their economic relations with the Third World. The Soviet apparatus can be particularly expedient at supplying military equipment and economic aid, or to engage in barter deals, depending on the political needs of the moment [Ref. 55].

Through the 45 years of the Cold War, the US and its allies maintained a military capability sufficient to convince the Soviets that the costs of aggression far outweigh any possible gain. Presenting a united front through the North Atlantic Treaty Organization(NATO), the West proved firm in their resolve to support and defend their security. The significant changes that swept Eastern Europe in 1989 and 1990 proves the soundness of the US strategy of nuclear and conventional deterrence, as it applies to the USSR.

Still, we should keep in mind that as each day passes, a stagnant deterrence strategy, without improved technologies, allows political and economic factors to have more weight in the strategic balance equation. As the US and USSR continue to find more common ground, and as they continue to move toward economic integration and mutually dependent economies, the US and its allies must reevaluate their understanding of the Soviet challenge. The US and its allies must recognize the East-West polarization, take the steps necessary to preserve our freedom, to ensure an effective deterrent to the threat and use of force, and to seek genuine and equitable arms reductions.

C. LIFE CYCLE COSTS.

One purposes of this study was to introduce the Life Cycle Cost (LCC) ideas within the Republic of Peru military and present the LCC application methodology in new weapon systems acquisition for the peruvian armed forces.

Life cycle costing can be an excellent management tool for controlling the total life cycle costs of a system during the acquisition process. Life cycle cost also can be a useful procurement technique in which to evaluate competing systems on the total cost over their useful life instead of basing a selection on initial acquisition cost.

The Republic of Peru still acquires most of its sophisticated weapon systems from foreign countries. Cost estimating plays an important role in the selection of the system. Yet, operating and support costs are increasing at an alarming rate

and often exceed the initial acquisition cost. Operating and support costs constitute about half the total LCC of an aircraft weapon system.

To capture these costs and rationally choose a weapon system based on total costs, not just acquisition costs, project managers should use life cycle cost estimating methodologies in today's acquisition process for the Peruvian military. Implementation of the ideas and methodologies presented in this thesis requires that the Peruvians change the procurement criteria they use within the Republic of Peru military to make operating and support costs a real factor in selecting weapon systems.

Life Cycle Cost analysis also showed that reliability and maintainability are the most important factors in determining operating and support costs. The Peruvians could get significant savings through investments early in the program that will increase system reliability and simplify maintenance. Fallibility and logistic supportability are design attributes, and their improvement will markedly increase system readiness. Thus, the Peruvians should emphasize reliability and maintainability of new weapon systems acquisition as key considerations.

Implementing life cycle cost analysis and techniques in the Peruvian military will improve considerably the decision making process in weapon systems acquisition programs. Simultaneously, a more rational view of future costs incurred by introduction of a new system into the organization will result in more accurate budget estimates.

Life cycle cost is not a panacea or a substitute for managerial decision making. It is an idea that fosters good management. By managing this idea effectively, the peruvian military managers can reduce the upward trend of operating and support costs, making more funds available to buy new systems to meet the growing military threat.

The Republic of Peru military must recognize the importance of these ideas and methodologies. Also, these ideas and methodologies must be reflected in the acquisition strategy and the logistics support management policy. To carry out the Life Cycle Cost analysis methodology during the weapon system acquisition process, the Peruvian military should:

1. Conduct training on Life Cycle Cost procurement policies and procedures at Service schools.

2. Develop computer based cost-estimating models. The use of Life Cycle Cost models will need accurate cost data on similar systems. Thus, the Peruvian military should develop a system that will collect and report operating and support costs by weapon system.

3. As early as concept development, the Peruvian military should use their logisticians in the acquisition process and involve the program managers and contractor personnel to stress the importance of support costs considerations.

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APPENDIX A: ECONOMIC ANALYSIS OUTLINE

I. INTRODUCTION

A. Background. Give a general overview of the existing environment and identify the specific area you studied. Provide a history of major events leading to the problem.

B. Scope. Identify the scope of your study.

C. Methodology. Summarize your procedures for conducting the analysis and the techniques you used in estimating and computing costs and benefits. Provide details in an appendix.

II. OBJECTIVE

State the major objectives of the program or project you studied. State objectives in terms of a functional need without implying how you will do them.

III. ASSUMPTIONS

State all the assumptions you used in your economic analysis. Include the expected economic life, period of comparisons and all constraints, limitations, or exclusions related to your analysis.

IV. ALTERNATIVES

Describe the technical and operational characteristics of the alternatives considered, including the current system.

A. Current System. The current system identifies the level of costs and benefits that would accrue if you did not change your present method of operation. A current system serves as a baseline you use to compare new possibilities.

B. Proposed System. Describe the idea for each alternative. Address but do not quantify infeasible alternatives.

V. COST ANALYSIS

Identify and describe cost elements for each alternative. Include the computations you used to devise total costs and describe in detail the method for developing cost estimates. Use tables, charts, graphs, mathematical models and other visual aids to help in presentation of costs.

VI. BENEFIT ANALYSIS

Identify and describe all benefits the implementation of each alternative would obtain. Quantify benefits whenever possible. Identify criteria used to measure benefits. Include your computations. Provide a general narrative description of intangible benefits. Do not include savings under benefits. They belong in your cost analysis section.

VII. COMPARISON OF ALTERNATIVES

Compare your alternatives using an appropriate economic analysis technique. Present results in a convenient fashion using charts, tables, graphs or other visual aids whenever possible. NOTE: Whenever the period of comparison is greater than three years, you must compare the alternatives in terms of discounted costs and benefits.

VIII. SENSITIVITY ANALYSIS

Describe the approach and assumptions you used for conducting your sensitivity analysis. Identify and display the results of your analysis for all alternatives for each factor tested. Use tables, graphs and charts to present data and include a narrative to highlight key points in your evaluation.

IX. CONCLUSIONS

Make your co lusion clear and concise. Your conclusion is a brief statement of the most important findings in your report. Do not introduce new material nor put justifying sentences in your conclusion. The body of your report should have done that already. Make your point and stop.

X. RECOMMENDATIONS

Your recommendations follow from your conclusions. Put your recommendations in brief, clear, positive statements. They must be suitable, feasible, and acceptable if they are to be a complete and workable solution to the problem.

APPENDIX B: ECONOMIC ANALYSIS CHECKLIST

1. **The Objective:**

   a. Did you clearly state your objective? Does it define the purpose of the program, project or activity under study?

   b. Can you realistically obtain the objective?

   c. Did you state the objective in terms of output or accomplishment?

   d. Did you state the output or accomplishments in discrete units?

   e. Did you specify the criteria for selection of a preferred course of action?

   f. Can you measure the progress toward attainment of the objective?

   g. Did you phrase the objective statement so that it does not unnecessarily limit the type and variety of potential alternatives?

   h. If you require a completion or implementation date, did you specify the date?

2. **The Assumptions and Constraints**

   a. Did you identify and explain all reasonable assumptions?

   b. Are your assumptions too restrictive? Too broad?

   c. Are your assumptions realistic and justified?

   d. Does each assumption have an identified basis?

   e. Do you use assumptions only when you can not get facts?

   f. Do your assumptions preclude other alternative solutions?

   g. Do your assumptions include economic life and future workload?

h. Did you establish a project period?

i. Did you consider funding and budget constraints?

j. Did you include space and construction requirements?

k. Did you include necessary geographical constraints?

3. **The Alternatives**

a. Are your alternatives feasible? Can they meet the stated objectives?

b. Are your alternatives well defined and discreet? Do they overlap?

c. Is the total number of alternatives sufficient? Have you omitted any feasible alternatives?

d. If adequate, did you use the status quo as a base for comparison?

e. If appropriate, did you evaluate lease versus buy?

f. Did you consider all feasible alternatives?

g. Did you identify alternatives you did not analyze with reasons for their omission?

h. If other government organizations can provide the desired product or service, did you include them as alternatives?

4. **The Cost Estimate**

a. Did you include all relevant costs?

b. Do implementation costs include shipping, installation, support and training requirements?

c. Do labor costs consider specific skill levels, fringe benefits, overtime and shift differentials?

d. Did you include future equipment replacement as an investment cost?

e. Did you consider current asset values of reutilized equipment? Is the method of determining these values adequate?

f. Are your cost factors current and supportable?

g. Did you show why you consider certain costs relevant and others not?

h. Did you properly identify cost estimates and is their quality proper for the status of the program?

i. Did you identify estimating relationships and methodologies and are they adequate?

j. Did you exclude sunk costs?

k. Did you consider opportunity costs?

l. Did you associate terminal value with any of the alternatives?

m. Did you evaluate future costs in terms of constant dollars?

n. If you include inflation or cost escalation, did you identify the rate and the source of the rate?

o. Did you figure out cost savings or avoidance only by comparison with the status quo?

p. Are the costs of any alternative part of the analysis of only that alternative, and not also as a cost savings in the evaluation of another alternative?

q. Did you discount cash flows using the 10% discount rate?

5. **The Benefits**

a. Did you find relevant benefits? Does the analysis ignore any portion of total output?

b. Do the benefits relate to the project objective?

c. Did you identify the benefits in discrete units, as much as possible?

d. Does the context of your analysis justify the criteria you used to measure benefits?

e. Did you define your estimating techniques?

f. Did you identify your information and estimate sources?

g. Did you use an expert opinion? Did these experts have proper credentials?

h. Did you identify and use logical, convincing quantitative assessments instead of quantitative measures of benefits?

i. Did you go too far in attempting to quantify what you could not quantify?

j. Did you identify and quantify negative aspects?

k. Did you exclude cost reductions (savings) from the benefit list to avoid double counting?

l. Did you develop a ranking or priority system for evaluating the importance of the benefits?

m. Did you tabulate all benefit information for ease of examination?

6. **Comparison of Alternatives**

   a. Did you compare alternatives using the proper techniques, such as present value, benefit/cost ratios or break-even analysis?

   b. Did you compare alternatives in relation to a common basis?

   c. Does the analysis seem free of bias favoring one alternative? Was their comparison fair?

   d. Did you use the same criteria, costing methods and time span for all the alternatives?

   e. Did you combine cost and benefit information for each alternative to show relationships?

   f. Did you adequately document the methods and sources of comparison?

7. **Sensitivity Analysis**

   a. Has the analysis important underlying uncertainties?

   b. Is there important technological uncertainty?

   c. Did you use ranges of values for unknown quantities?

   d. Did you show the effects of future states of nature?

   e. Did you use break-even analysis to help evaluation of future uncertainties?

   f. Would you keep your recommendation if unknown characteristics varied within a feasible range?

   g. Did you illustrate the impact of the length of time for formal project approval?

h. Is the analysis too optimistic in its assumptions?

i. Is there a sensitivity analysis to show the effect of uncertainty in major cost estimates?

8. **Conclusions and Recommendations**

a. Are the results of the anaiysis conclusive? Can you establish a concrete ranking of alternatives?

b. Did you recommend a specific course of action?

c. Did you logically derive your conclusions and recommendations from the material?

d. Did you emphasize all significant differences between the recommended alternative and others?

e. Are the recommendations feasible considering politics, culture, and policy?

f. Did you base the recommendations upon significant differences between the alternatives?

g. Are your recommendations satisfying and supportable?

APPENDIX C: ECONOMIC ANALYSIS EXAMPLE

ECONOMIC ANALYSIS OF THE REPLACEMENT OF ADPE

I. INTRODUCTION

A. Background. At our installation, the user's demand for information services has saturated our computer. To do our current workload, we operate our computer around-the-clock, at full capacity. In addition, we do our workload using commercial timesharing services. We expect our workload to continue to grow each year. Since our work has saturated the in-house computer, we use timesharing to handle the growing workload. Due to the high timesharing costs, our Commander directed that we investigate the feasibility of replacing our current hardware with a larger, more efficient machine. Replacement of the current equipment would allow the activity to bring all timesharing workload in house. In addition it would allow the activity to complete its workload operating two shifts per day instead of three, thus reducing personnel costs by 1/3.

B. Scope. In keeping with GSA policy, the analysis examined their placement of current equipment under a competitive procurement. Thus, we did not consider the alternative to augment current equipment with compatible equipment via a sole source procurement.

C. Methodology. For this analysis, we compared the costs and benefits of the proposed ADPE procurement with the current system. we did this by first examining the current and projected ADP workload at our activity. Once we set the workload, we figured out the ADPE requirements for a new Brand Z computer and the future timesharing requirements under the current system. We found costs and benefits for both alternatives. We compared the alternatives in terms of their present value costs over a nine year period. We did a sensitivity analysis to decide what degree of changes in certain cost factors would affect the results of the analysis.

II. OBJECTIVE

The objective of this analysis is to examine the economic feasibility of replacing the existing ADP system with new equipment.

III. ASSUMPTIONS

A. The new system must be large enough to support the current in-house and timesharing work load and projected workload growth throughout the life cycle.

B. The economic life of the system is seven years from the point of full implementation.

C. Only major vendors can absorb the cost of running the bench mark, therefore, only major vendors will bid.

D. The two compatible vendors will continue their practice of non-competitive bidding, thus the procurement will result in non-compatible equipment.

E. To transfer the in-house workload to the Brand Z computer will require six months. To transfer the timesharing workload will require three months.

G. All new applications developed after the installation of the new equipment will use the new equipment without conversion.

H. We will lease ADPE.

I. All costs and salaries reflect those in effect during the current fiscal year. We made no provision for inflation.

J. MILCON funding will be available for construction of additional space.

K. Figure C-1 shows major milestones for the proposed alternatives.

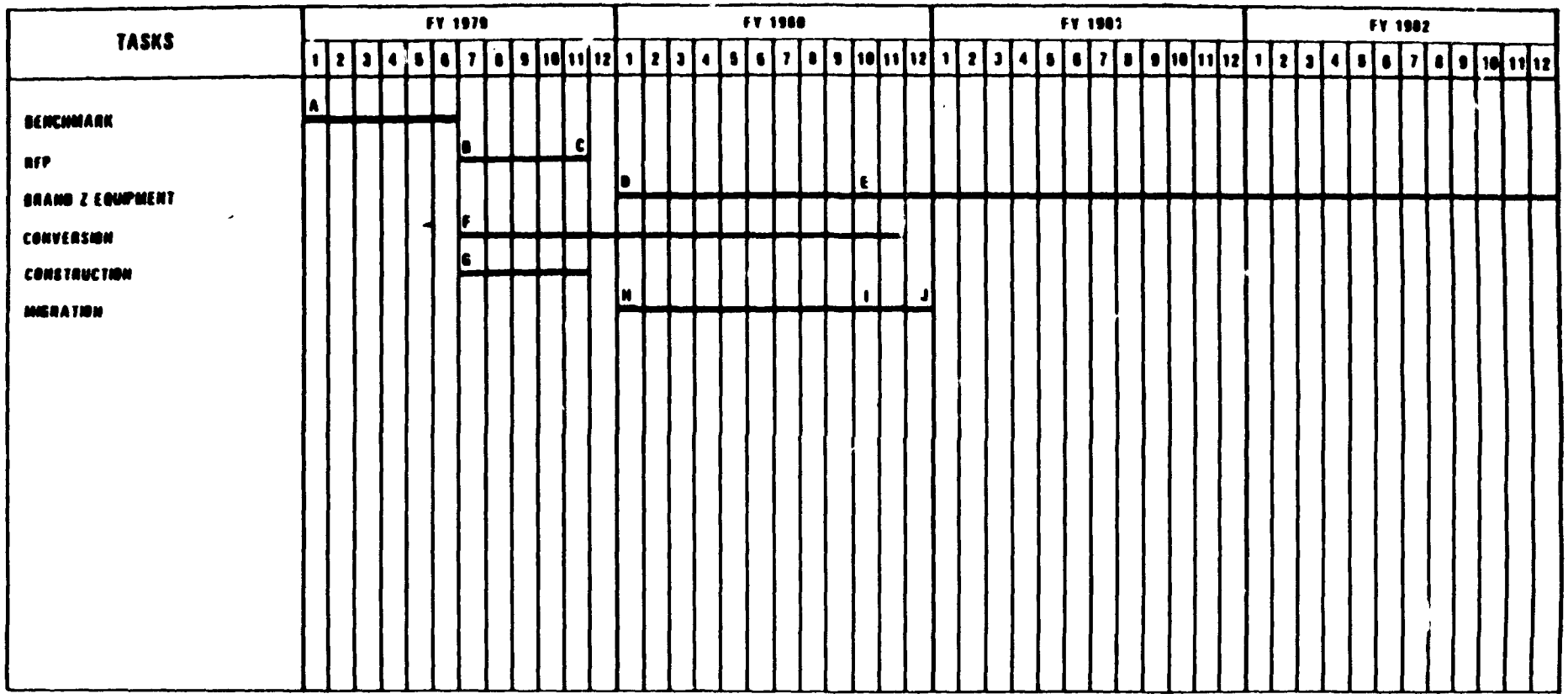
IV. ALTERNATIVES

A. Current System. We will continue to operate the computer center as we do today. Because the computer center already operates three shifts per day at full capacity, we will require no additional staffing nor in-house operating costs in the out years. We will support all new workload through commercial timesharing.

B. Brand Z System. We will replace the existing ADP equipment through a traditional competitive procurement. Contractors, with the help of in-house personnel, will make a bench mark package. We will require the vendors to run the bench mark at their expense. We will award the contract to the best vendor. We will do massive conversion effort to make all existing programs compatible with the new equipment. The migration of in-house workload will occur three months after contract award and take eight months to complete. The migration of the timesharing workload will occur one year after contract award and take two months to complete. Then, we will release the current system. Once the Brand Z system is fully operational, we will reduce operations from three to two shifts per day. At this time, we will transfer nearly 1/3 of the personnel.

Figure C-1

MAJOR MILESTONES



A BEGIN BENCHMARK CONSTRUCTION

B ISSUE RFP

C AWARD BRAND Z CONTRACT

D INSTALL BRAND Z EQUIPMENT

E RELEASE CURRENT EQUIPMENT

F BEGIN CONVERSION

G BEGIN CONSTRUCTION

H BEGIN MIGRATION OF INHOUSE WORKLOAD

I BEGIN MIGRATION OF TIMESHARING WORKLOAD

J SYSTEM IS FULLY OPERATIONAL

V. COST ANALYSIS

We estimate nonrecurring and recurring costs for each alternative. Nonrecurring costs are those costs made once, only!. Recurring costs are those costs incurred repeatedly, throughout the project life. Tables C-1 through C-3 shows the nonrecurring and recurring costs. Cost elements are:

A. Nonrecurring Costs

1. Bench Mark Construction. We will contract-out the bench mark package for an estimated cost of $335,000. A six person bench mark team will help the contractors to prepare the bench mark package. The cost of the bench mark team includes salaries, travel, per diem and miscellaneous expenses for a six-week period. Based on a GS-13 step five, the salary and fringe benefits will cost $4523 per person. We estimate travel costs for three trips at a transportation cost of $1000 per person and per diem for 42 days at $75 per day. Other expenses include rental cars for six weeks at $300 per car per week. The total cost for the bench mark team is $55,638.

2. Conversion. We used NAVDAC's Project Management Control System (PMCS) to project our conversion costs. We will co tract out the conversion at a cost of $45,000 per labor-year. The conversion effort will require 125 labor-years and will take place over a 17 month period. The total conversion cost is $ 5,625,000.

3. Construction. Alternative B requires additional floor space for the Brand Z equipment. Total construction cost is $1,263,200. This is for construction of 8,000 square feet at $ 129 per square foot to house the computers and support equipment and construction of 3400 square feet at $68 per square foot to house the Uninterruptable Power Supply (UPS) upgrade.

4. Initial Computer Room Equipment. We will install miscellaneous computer room support equipment (tape storage racks, tape cleaner , tables, console operator chairs, among others) to support the initial Brand Z equipment. This equipment will cost $30,000.

5. Upgrade of UPS System. Brand Z equipment draws more electricity than our current equipment and require an initial UPS upgrade of 50 KVA. In year four, this will require an additional upgrade of 650 KVA. The costs of the upgrades in years one and four are $610,100 and $725,500.

TABLE C-1
NONRECURRING COSTS ($000)
ALTERNATIVE: B

COST CATEGORY	FY79	FY80	FY81	FY82	TOTAL
Benchmark Construction					
a. Benchmark Package	$335.0				$335.0
b. In-house Benchmark Team	46.9				46.9
Conversion	1985.3	$3639.7			5625.0
Construction	1263.2				1263.2
Computer Room Equipment		30.0			30.0
UPS Upgrade	610.1			$723.5	1333.6
Migration of Workload					
a. In-house Workload		707.2			707.2
b. Timesharing Workload		283.2			283.2
Supplies		174.2			174.2
Utilities					
a. Computer power		110.6			110.6
b. General Utilities		47.4			47.4
Personnel Separation		105.2			105.2
Terminal Value of Owned Equipment		(1650.0)			(1650.0)
TOTALS	$4240.5	$3447.5		$723.5	$8411.5

TABLE C-2
RECURRING COSTS ($000)
ALTERNATIVE A

COST CATEGORY	FY79	FY80	FY81	FY82	FY83	FY84	FY85	FY86	FY87	TOTAL
ADP Timesharing	$ 320.9	$ 704.9	$1387.6	$1804.5	$2344.1	$3049.2	$3963.6	$5151.8	$6696.6	$25,523.4
ADPE Rental/Maintenance	4248.0	4248.0	4248.0	4248.0	4248.0	4248.0	4248.0	4248.0	4248.0	38,232.0
Utilities										
Computer Power	248.0	248.0	248.0	248.0	248.0	248.0	248.0	248.0	248.0	2232.0
General Utilities	106.6	106.6	106.6	106.6	106.6	106.6	106.6	106.6	106.6	959.4
Personnel	3616.8	3616.8	3616.8	3616.8	3616.8	3616.8	3616.8	3616.8	3616.8	32,551.2
Supplies	550.0	550.0	550.0	550.0	550.0	550.0	550.0	550.0	550.0	4950.0
TOTAL	$9191.1	$9875.1	$10,157.8	$10,574.7	$11,114.5	$11,819.4	$12,733.0	$13,922.0	$15,466.0	$104,455.2

TABLE C-3
RECURRING COSTS ($000)
ALTERNATIVE B

COST CATEGORY	FY79	FY80	FY81	FY82	FY83	FY84	FY85	FY86	FY87	TOTAL
ADP Timesharing	$ 420.9	$ 420.9								$ 841.8
ADPE Rental/Maintenance										
Current Equipment	4,248.0	3,186.0								7,434.0
Brand Z Equipment		4,825.0	$4,825.0	$4,825.0	$4,825.0	$4,825.0	$4,825.0	$4,825.0	$4,825.0	38,600.0
Utilities										
Computer Power	248.8	235.0	276.5	290.3	304.8	320.1	336.1	352.9	370.5	2,735.0
General Utilities	106.6	100.7	118.5	124.4	130.6	137.2	144.0	151.2	158.8	1,172.0
Personnel	3,616.8	3,315.4	2,411.2	2,531.8	2,658.3	2,791.3	2,930.8	3077.4	3,231.2	26,564.2
Supplies	550.0	550.0	577.5	606.4	636.7	668.5	702.0	737.1	773.9	5,802.1
TOTAL	$9,191.1	$12,613.0	$8,208.7	$8,377.9	$8,555.4	$8,742.1	$8,937.9	$9,143.6	$9359.4	$81,149.1

6. Migration of Workload. Migration is the transfer of the in-house and timesharing workload to the Brand Z equipment. We will migrate using in-house personnel paid overtime. Based on the MPCS, the effort will require 9,600 hours of overtime (49,700 hours for the in-house workload and 19,900 hours for the timesharing workload). We estimated the
costs of the migration effort using the overtime rate for a GS-6 step five. The hourly overtime costs including fringe benefits and leave is $14.23 per our. Thus, the migration costs for the in-house and timesharing workloads are $707,200 and 283,200.

7. Supplies. We estimate that the migration will use $ 174,200 of supplies.

8. Utilities. The migration effort will use approximately 400 KVA of electricity. Based on a NAVFAC estimating formula, the computer power cost is $110,600 (400 KVA x .8 usage factor x $.04 cost factor x 720 hours per month x 12 months). Experience shows that the computer power requirement represents 70% of the total utilities cost, while general utilities including air conditioning, lighting, and others, comprise the remaining 30%. Based on this information, the general utilities cost is $47,400.

9. Personnel Separation Costs. The elimination of the third shift will reduce personnel requirements by 1/3 (eight military, 64 civilians). We will reduce the military billets through normal attrition. Since we routinely transfer military personnel to new duty stations when they finish their tour, we incur no additional separation costs.

We will give priority rights to civilian employees whose jobs we eliminate, to move them to other vacant positions in DOD and other Federal agencies. Based on DOD experience, approximately 75% of the displaced workers will find other jobs or retire. We will force separate the other 25%. The estimated cost to separate an employee is $6575. Thus, the estimated separation cost for 16 civilians is $105,200.

10. Terminal Values of Owned Equipment. The Government owns part of the current equipment. When Brand Z is fully operational, we can release this equipment for sale or reutilization by other government activities. The projected market value for the equipment at the time of its release is $ 1,650,000.

B. Recurring Costs

1. ADP Timesharing. Because our current workload has saturated our computer, we use commercial timesharing to do the excess work. The cost for the timesharing services is $2014 per CPU hour. Unless we get new equipment, we expect to use more timesharing each year to meet the ADP workload growth. Table C-4 shows projected timesharing workload and its costs.

TABLE C - 4
PROJECTED TIMESHARING
WORKLOAD

Year	CPU Hours	Costs
1	209	$420,900
2	350	704,900
3	689	1,387,600
4	896	1,804,500
5	1164	2,344,300
6	1514	3,049,200
7	1968	3,963,600
8	2558	5,151,800
9	3325	6,696,600
		$25,523,400

2. ADPE Rental/Maintenance

a. Current Equipment. Annual rental/maintenance for the current ADPE is $4,248,000. Under Alternative A, we incur this cost throughout the project life. Under Alternative B, we will incur this cost until we release the equipment.

b. Brand Z Equipment. The annual rental/maintenance for Brand Z equipment is $4,825,000.

3. Utilities

a. Current Equipment. The current equipment uses 900 KVA to do the in-house workload. Based on the NAVFAC formula, the computer power cost is $248,800 (900 KVA x .8 usage factor x .04 cost factor 720 hours per month x 12 month per year). The cost for general utilities is $106,600. Since our current workload saturates our equipment, we made no provisions for workload growth.

b. Brand Z Equipment. The Brand Z equipment needs 700 KVA to do the current in-house workload and 300 KVA to do the initial timesharing workload. Based on the NAVFAC formula, the utilities cost for the first year of full use is $276,500 for computer power and $118,500 for general utilities. After that, utilities costs will increase 5% each year due to workload growth.

4. Personnel. We based civilian personnel costs on current annual salaries and adjusted the pay rates and salaries per the Office of Management and Budget guidance to include a 26% fringe benefit factor. We based military personnel costs on the composite military pay rates identified in the NAVCOMPT manual. We adjusted these to include a 29% fringe benefit factor for officers and a 40% factor for enlisted personnel.

a. Alternative A. The computer activity currently runs three shifts per day, requiring 216 people. Table C-5 identifies personnel costs. The annual personnel costs are approximately $3,616,800 and will remain constant throughout the life cycle.

TABLE C - 5
CURRENT PERSONNEL REQUIREMENTS

Grade	Number of People	Annual Salary	Salary + Fringe Benefits	Personnel Costs
E-5	12	$11,507	$16,100	$193,320
E-4	9	9,747	13,646	122,814
0-5	3	34,047	42,559	127,677
GS-7	24	14,750	18,585	446,040
GS-6	120	13,272	16,723	2,006,760
GS-5	48	11,907	15,003	720,144
Totals	216			$3,616,755

b. Alternative B. Alternative B will operate with current personnel until 1 July of the first year after implementation when the Brand Z equipment becomes fully operational for the in-house workload. Then, we will release the current equipment and run two shifts per day, reducing initial personnel requirements by 1/3 Personnel costs to support initial requirements are $2,411,200. Table C-6 shows these costs. After 1 July, we expect personnel costs to increase by five percent due to the growth in workload.

TABLE C-6
INITIAL PERSONNEL REQUIREMENTS FOR BRAND Z

Grade	Number of People	Annual Salary	Salary + Fringe Benefits	Personnel Costs
E-5	8	$11,507	$16,110	$128,880
E-4	6	9,747	13,646	81,876
0-5	2	34,047	42,559	85,118
GS-7	16	14,750	18,585	297,360
GS-6	80	13,272	16,723	1,337,840
GS-5	32	11,907	15,003	480,096
Totals	144			$2,411,170

5. Supplies

a. Alternative A. The current cost for forms, cards ribbons and other ADP related supply items is $550,000 per year. For alternative A, this value will remain constant throughout the life cycle.

b. Alternative B. For years one and two, supplies are the same as Alternative A. Starting in year three, supply costs increase 5% per year due to the increased workload.

VI. BENEFIT ANALYSIS

We identified some benefits and disadvantages with the proposed alternative.

A. Benefits

1. We can do our work faster, giving in better turnaround time for the users.

2. The new equipment has better reliability and has less chance to crash. If the system does fail, it will be easier to repair. Thus, this will reduce downtime of the system.

3. The new equipment will provide greater accuracy and eliminate batch processing. Data entry will be key to disk, thus eliminating keypunch errors. Reduction of input error will result in fewer corrections and fewer reruns.

4. The new equipment will retain a 33% surge capacity (third shift) to support crisis and exercise operation.

5. The current system does not meet minimum security requirements. We designed the proposed alternative to provide high security environment.

B. Disadvantages

1. The continuity of operation will be interrupted during the migration period. The current staff is proficient in running the existing equipment. Still, they will require special training and on the job experience to become equally proficient in operating the new equipment.

2. The proposed alternative requires MILCON funding. If we do not get MILCON funding, we must delay our implementation.

3. This will eliminate many jobs in a geographic area with a high unemployment rate and depressed economy.

VII. COMPARISON OF ALTERNATIVES

A. Present Value Analysis. We did a present value analyses on Alternatives A and B. Tables C-7 and C-8 present this analysis. The results show that the discounted life cycle cost for the current system is $67,331,200 and the discounted life cycle cost of the proposed system is $63,947,900. Thus, the proposed system is economically feasible, yielding net discounted savings of $3,383,300.

B. Break-Even Analysis. Figure C-2 graphically displays the cumulative discounted costs for each alternative. The break-even point, when the cumulative costs for both alternatives are equal, occurs six years after implementation. Before then, Alternative A is less costly. After that, Alternative B becomes cost advantageous.

VIII. SENSITIVITY ANALYSIS

We did a sensitivity analysis to find if changes in certain input values would affect the outcome of our analysis. We tested three variables: conversion costs; Brand Z ADPE rental/maintenance and; timesharing workload. We tested each factor independently by changing the original estimate by ten, 25 and 50 percent while holding all other parameters constant. Then, we calculated discounted life cycle costs for each alternative based on the new estimates. Below are the results of the three tests:

A. Conversion Costs. Table C-9 show what would happen if conversion costs were 10%, 25%, and 50% higher than the original estimate. Since we would incur conversion costs only under the proposed alternative, the discounted life cycle cost of $67,331,200 for Alternative A will remain unchanged. Discounted life cycle costs for Alternative B would be:

	Undiscounted Conversion Costs		Discounted Life-Cycle Costs
	1979	1980	
Original estimate	$1,985,300	$3,639,700	$63,947,900
+10%	2,183,800	4,003,700	64,452,800
+25%	2,481,600	4,549,600	65,210,200
+50%	2,978,00	05,459,600	66,472,700

TABLE C-7

PRESENT VALUE ANALYSIS

ALTERNATIVE: A

($000)

PROJECT YEAR	NONRECURRING COSTS	RECURRING COSTS	TOTAL COST	DISCOUNT FACTOR	DISCOUNTED COSTS	CUMULATIVE DISCOUNTED COSTS
FY79		9,191.1	9,191.1	.954	8,768.3	8,768.3
FY80		9,475.1	9,475.1	.867	8,214.9	16,983.2
FY81		10,157.8	10,157.8	.788	7,980.7	24,963.9
FY82		10,574.7	10,574.7	.717	7,582.1	32,546.0
FY83		11,114.5	11,114.5	.652	7,246.7	39,792.7
FY84		11,819.4	11,819.4	.592	6,997.1	46,789.8
FY85		12,733.8	12,733.8	.538	6,850.8	53,640.6
FY86		13,922.0	13,922.0	.489	6,807.9	60,448.5
FY87		15,466.8	15,466.8	.445	6,882.7	67,331.2

TABLE C-8

PRESENT VALUE ANALYSIS

ALTERNATIVE: B

($000)

PROJECT YEAR	NONRECURRING COSTS	RECURRING COSTS	TOTAL COST	DISCOUNT FACTOR	DISCOUNTED COSTS	CUMULATIVE DISCOUNTED COSTS
FY79	$4,240.5	$ 9 191.1	$13,431.6	.954	$12,813.7	$12,813.7
FY80	3,447.5	12,633.0	16,080.5	.867	13,941.8	26,755.5
FY81		8,208.7	8,208.7	.788	6,468.5	33,224.0
FY82	723.5	8,377.9	9,101.4	.717	6,525.7	39,749.7
FY83		8,555.4	8,555.4	.652	5,578.1	45,327.8
FY84		8,742.1	8,742.1	.592	5,175.3	50,503.1
FY85		8,937.9	8,937.9	.538	4,808.6	55,311.7
FY86		9,143.6	9,143.6	.489	4,471.2	59,782.9
FY87		9,359.4	9,359.4	.445	4,164.9	63,947.9

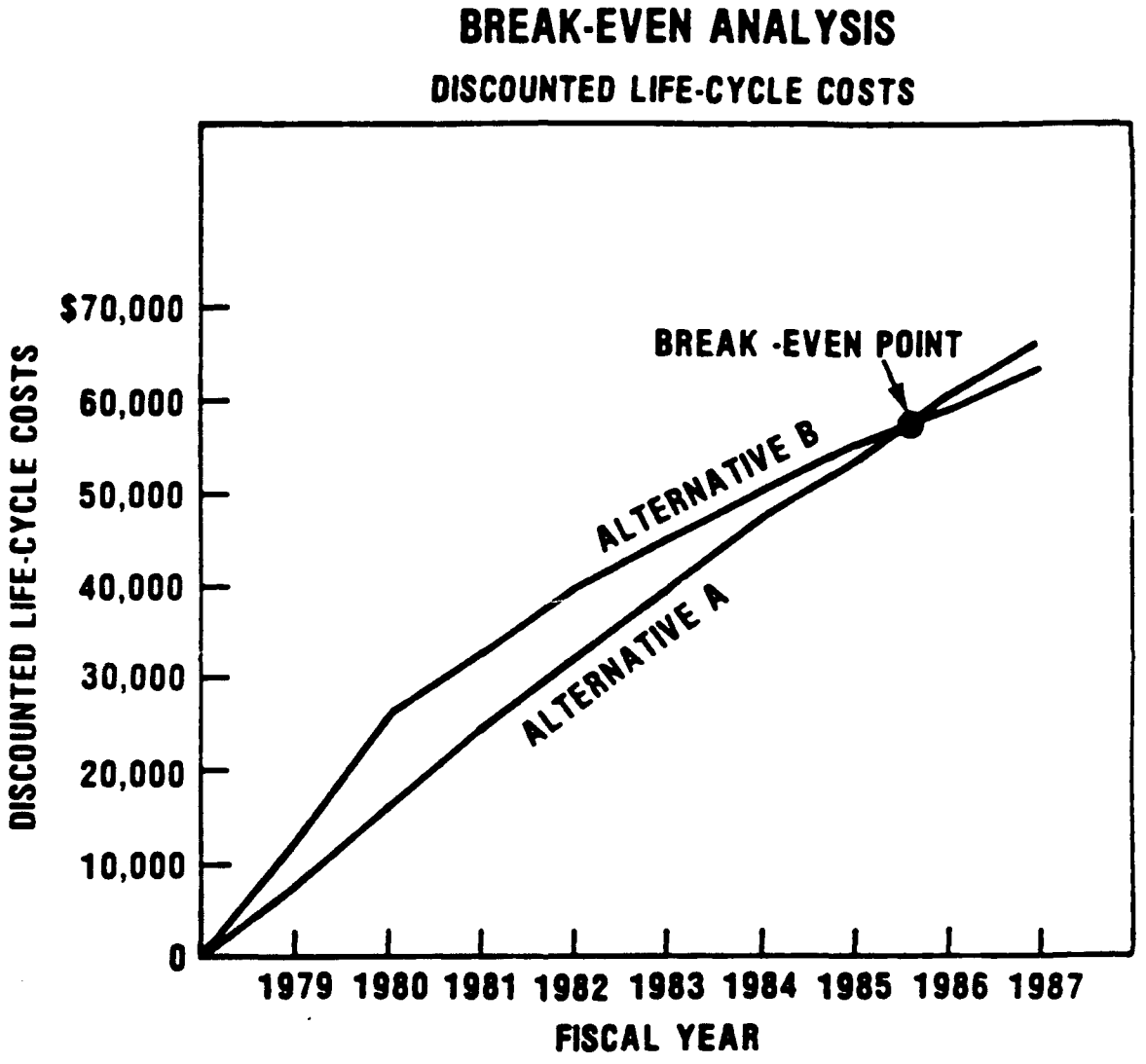

BREAK-EVEN ANALYSIS
DISCOUNTED LIFE-CYCLE COSTS
DISCOUNTED LIFE-CYCLE COSTS
$70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
BREAK -EVEN POINT
ALTERNATIVE B
ALTERNATIVE A
1979 1980 1981 1982 1983 1984 1985 1986 1987
FISCAL YEAR

Figure C-2

TABLE C-9

SENSITIVITY ANALYSIS

CONVERSION COSTS

($000)

FISCAL YEAR	DISCOUNT FACTOR	ALTERNATIVE A		ALTERNATIVE B					
		NO CHANGE		10% CHANGE		25% CHANGE		50% CHANGE	
		UNDISCOUNTED COST	CUMULATIVE DISCOUNTED COST	UNDISCOUNTED COST	CUMULATIVE DISCOUNTED COST	UNDISCOUNTED COST	CUMULATIVE DISCOUNTED COST	UNDISCOUNTED COST	CUMULATIVE DISCOUNTED COST
FY79	.954	$ 9,191.1	$ 8,768.3	$13,630.1	$13,003.1	$13,927.9	$13,287.2	$14,424.3	$13,760.8
FY80	.867	9,475.1	16,983.2	16,444.5	27,260.5	16,990.4	28,017.9	17,900.4	29,280.4
FY81	.788	10,157.8	24,963.9	8,208.7	33,729.0	8,208.7	34,486.4	8,208.7	35,748.9
FY82	.717	10,574.7	32,546.0	9,101.4	40,254.7	9,101.4	41,012.1	9,101.4	42,274.6
FY83	.652	11,114.5	39,792.7	8,555.4	45,832.8	8,555.4	46,590.2	8,555.4	47,852.7
FY84	.592	11,819.4	46,789.8	8,742.1	51,008.1	8,742.1	51,765.5	8,742.1	53,028.0
FY85	.538	12,733.8	53,640.6	8,937.9	55,816.7	8,937.9	56,574.1	8,937.9	57,836.6
FY86	.489	13,922.0	60,448.5	9,143.6	60,287.9	9,143.6	61,045.3	9,143.6	62,307.8
FY87	.445	15,466.8	67,331.2	9,359.4	64,452.8	9,359.4	65,210.2	9,359.4	66,472.7

In each cases, life cycle costs for Alternative B are less than Alternative A. Thus, the analysis is not sensitive to changes in conversion costs at these levels. We note sensitivity when we increase conversion costs by 67 percent. We found this value by doing the following algebraic break-even analysis.

Alternative A = Alternative B

$67,331.2 = $63,947.9 + $1985.3x (.954) + $3939.7x (.867)

$3,383.3 = $1894.Ox + $ 3,155.6x

3,383.3 = $5049.6x

x = .67

B. Brand Z ADPE Rental/Maintenance. Table C-10 shows what would happen if Brand Z ADPE costs increased by 10%, 25% and 50%. This would not affect Alternative A. Costs for Alternative B would be:

	Annual Brand Z ADPE	Discounted Life Cycle Costs
Original Estimate	$4,825,000	$63,947,900
+10%	5,307,500	66,402,900
+25%	6,031,300	70,085,300
+50%	7,237,500	76,222,700

The economic analysis is not sensitive to a 10 % change. It is sensitive to changes of 25% and 50%. The actual point of sensitivity occurs when we increased Brand Z ADPE costs by 13.8% as follows:

Alternative A = Alternative B

$67,331.2 = $63,947.9 + $4,825x (5.088)

$3,383.3 = $24,549.6x

x = .138

TABLE C-10
SENSITIVITY ANALYSIS
BRAND Z ADPE COSTS
($000)

FISCAL YEAR	DISCOUNT FACTOR	ALTERNATIVE A		ALTERNATIVE B					
		NO CHANGE		10% CHANGE		25% CHANGE		50% CHANGE	
		UNDISCOUNTED COST	CUMULATIVE DISCOUNTED COST	UNDISCOUNTED COST	CUMULATIVE DISCOUNTED COST	UNDISCOUNTED COST	CUMULATIVE DISCOUNTED COST	UNDISCOUNTED COST	CUMULATIVE DISCOUNTED COST
FY79	.954	$ 9,191.1	$ 8,768.3	$13,431.6	$12,813.7	$13,431.6	$12,813.7	$13,431.6	$12,813.7
FY80	.867	9,475.1	16,983.2	16,563.0	27,173.8	17,286.8	27,801.4	18,493.0	28,847.1
FY81	.788	10,157.8	24,963.9	8,691.2	34,022.5	9,415.0	35,220.4	10,621.2	37,216.6
FY82	.717	10,574.7	32,546.0	9,583.9	40,894.2	10,307.7	42,611.0	11,513.9	45,472.1
FY83	.652	11,114.5	39,792.7	9,037.9	46,786.9	9,761.7	48,975.6	10,967.9	52,623.2
FY84	.592	11,819.4	46,789.8	9,224.6	52,247.9	9,948.4	54,865.1	11,154.6	59,226.7
FY85	.538	12,733.8	53,640.6	9,420.4	57,316.1	10,144.2	60,322.7	11,350.4	65,332.2
FY86	.489	13,922.0	60,448.6	9,626.1	62,023.3	10,349.9	65,383.8	11,556.1	70,984.1
FY87	.445	15,466.6	67,331.2	9,841.9	66,402.9	10,565.7	70,085.5	11,771.9	76,222.6

TABLE C-11
SENSITIVITY ANALYSIS

TIMESHARING WORKLOAD

($000)

FISCAL YEAR	DISCOUNT FACTOR	ALTERNATIVE A						ALTERNATIVE B					
		10% CHANGE		25% CHANGE		50% CHANGE		10% CHANGE		25% CHANGE		50% CHANGE	
		UNDISCOUNTED COST	CUMULATIVE DISCOUNTED COST	UNDISCOUNTED COST	CUMULATIVE DISCOUNTED COST	UNDISCOUNTED COST	CUMULATIVE DISCOUNTED COST	UNDISCOUNTED COST	CUMULATIVE DISCOUNTED COST	UNDISCOUNTED COST	CUMULATIVE DISCOUNTED COST	UNDISCOUNTED COST	CUMULATIVE DISCOUNTED COST
FY79	.954	8,728.1	8,728.1	9,085.9	8,667.9	8,980.6	8,567.5	11,389.5	12,771.6	11,326.4	12,713.4	11,221.1	12,612.9
FY80	.667	8,153.8	16,881.9	9,298.9	16,730.0	9,122.6	16,476.8	16,038.4	26,678.9	15,975.3	26,564.0	15,870.0	26,372.2
FY81	.708	7,895.0	24,881.9	9,810.9	24,461.0	9,464.0	23,914.4	8,208.7	33,147.4	8,208.7	33,032.5	8,208.7	32,840.7
FY82	.717	7,452.6	32,229.5	10,121.6	31,719.6	9,672.4	30,869.5	9,101.4	39,673.1	9,101.4	39,558.2	9,101.4	39,166.4
FY83	.652	7,093.8	39,323.3	10,528.4	38,584.1	9,942.3	37,351.9	8,555.4	45,251.2	8,555.4	45,136.3	8,555.4	44,944.5
FY84	.592	6,816.9	46,140.2	11,057.1	45,129.9	10,294.8	43,446.4	8,742.1	50,420.5	8,742.1	50,311.6	8,742.1	50,119.8
FY85	.538	6,637.5	52,777.7	11,742.9	51,447.6	10,752.0	49,241.0	8,937.9	55,215.1	8,937.9	55,120.2	8,937.9	54,928.4
FY86	.489	6,555.9	59,333.6	12,634.0	57,625.6	11,446.1	54,779.2	9,143.6	59,706.3	9,143.6	59,591.4	9,143.6	59,399.6
FY87	.445	6,584.7	65,918.1	13,792.6	63,761.3	12,118.5	60,171.9	9,359.4	63,871.2	9,359.4	63,756.3	9,359.4	63,564.5

C. Timesharing Workload. Projected growth in timesharing workload was a major factor that led to the proposal to replace existing equipment. Because of the uncertainties associated with projecting future workload, we did a contingency analysis to see what happens if future workload is less than our projection. Table C-11 shows the results of the analysis. The future workload would affect both alternatives as we would incur the timesharing costs in either case. As Table C-4 identified, timesharing workloads decreased by 10%, 25% and 50%. The associated discounted life cycle costs are:

Alternative A	Alternative B
$65,918,100	$63,871,200
63,763,300	63,756,300
60,171,900	63,564,500

The results show that the analysis is not sensitive at the 10% level. At the 25% level life cycle costs are about equal for both alternatives. This is the break-even point. If we decrease the timesharing workload by more than 25%. Alternative B would not be the least costly alternative.

IX. CONCLUSION

The results of the economic analysis showed that the proposed alternative is economically feasible. The alternative becomes cost effective six years after implementation and yields discounted life cycle savings of $3,383,300. We attribute major savings to the elimination of the timesharing workload. Besides being less costly, Alternative B can process the workload with greater speed, accuracy and reliability.

X. RECOMMENDATION

Based on the results of the economic analysis, we recommend Alternative B for implementation.

APPENDIX D

REVISED ECONOMIC ANALYSIS PROCEDURES

This appendix is the revised publication. Because it is in book form, this study did not continue the thesis page numbering into the document. The page numbering continues on the distribution list.

TABLE OF CONTENTS

Chapter 5 - Cost Estimating Techniques

Chapter 6 - Benefit Quantification

Chapter 7 - Economic Life and Project Life

Chapter 8 - The Notion of Present Value

Chapter 9 - Government Discount Rate

CHAPTER 1

THE CONCEPT OF ECONOMIC ANALYSIS

INTRODUCTION

For personnel who have little or no experience with economic analyses, this book establishes a routine to perform economic analysis. Supervisors and functional managers who must initiate or review economic analyses will also find this book of value. While you can easily apply the techniques described here to all types of investments, this book deals with the economic problems of choice in the acquisition of information technology.

ECONOMIC ANALYSIS DEFINED

Economic analysis is a systematic approach to evaluating alternative projects. The technique keys on the premise that alternative ways of reaching an objective exist and each alternative requires certain resources and produces certain results. Economic analysis relates costs, benefits, and uncertainties of each alternative in order to determine the most cost effective means of meeting an objective. It is not a search for the cheapest solution regardless of effectiveness.

You must incorporate three basic principles in the economic analysis:

1. You must investigate all reasonable alternative methods of satisfying a given objective.

2. You must consider both current and future expenditure patterns of all the alternatives.

3. Because of the "time value of money", you must consider not only how much a proposal will cost, but also when you will make the expenditures. To include this consideration in the analysis you express each alternative's life cycle costs in terms of its present value.

USES OF ECONOMIC ANALYSIS

Generally, you use economic analysis two ways: First, to assess the economic consequences of a past decision. Second, to assess the economic consequences of a future decision. As Figure 1-1 shows, the distinction lies in the relationship of the analysis to the planning and decision process.

USES OF ECONOMIC ANALYSIS

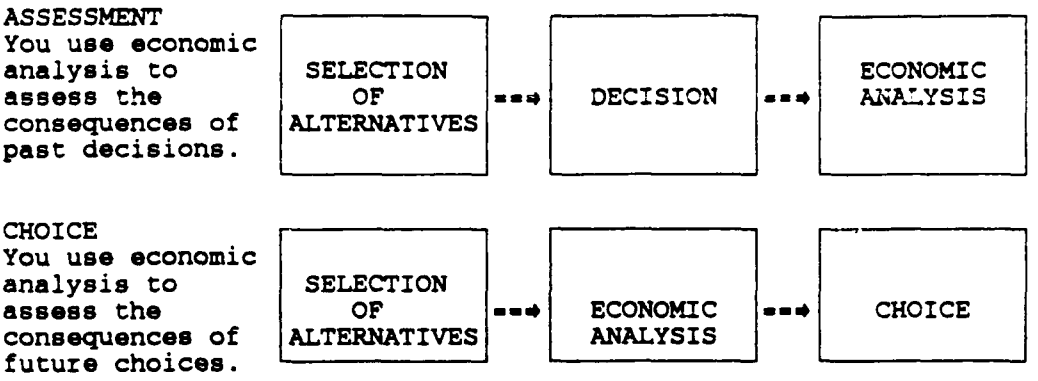


Figure 1-1

The first use, assessment, assumes that you already have made a decision. You can use the results to determine a future course of action. For example, suppose you run a data processing installation. In order to recoup your costs, you decide to implement a charge back system. You perform an economic analysis to assess all costs associated with operating the installation. Using this information, you could then determine an equitable means of charging your customers.

The second use, choice, assumes that you will make a decision based on the economic consequences of alternatives. For example, suppose that the space in your computer room is inadequate. You must choose among building a new space, renovating the old space, buying or renting another facility, or remaining with the status quo. In this case, you do not make a decision until you have evaluated the costs and benefits of each alternative.

ECONOMIC ANALYSIS AND THE BUDGET

An economic analysis seldom leads to cost estimates consistent with your budget. This inconsistency occurs for several reasons. First, a budget is a spending plan reflecting actual out of pocket expenses you expect to incur. An economic analysis considers not only out of pocket costs, but also opportunity costs, such as resources already on hand that have alternative uses. Second, many budgets reflect past spending trends in an unstructured environment. Economic analysis develops future cash flows and projected costs in a structured environment. Third, you always include fringe benefits in an economic analysis. Finally, an economic analysis states future costs and benefits in terms of their present value.

LIMITATIONS

Economic analysis is subject to a number of limitations. First, economic analysis does not normally establish priorities among various goals and objectives. Rather, economic analysis merely seeks to determine the most cost effective means to satisfy a given objective.

Second, an economic analysis is not a process for choosing the preferred means of meeting an objective. Economic analysis is only an input to the decision making process. You must weigh the results of the economic analysis against other factors, such as safety, health, morale, environmental impact, political considerations, and national priorities. Economic analysis is not a substitute for sound judgement. By systematically quantifying what you can quantify, economic analysis lets you focus your judgement on the areas vital to your decision.

Finally, an economic analysis cannot provide results which are more valid than the input data. Judicious formulation of assumptions and careful estimation of costs and benefits are critical to the economic analysis process.

Yet, no matter how much care you exercise during these stages, you cannot completely eliminate uncertainty. Economic analysis necessarily involves assumptions, projections, and estimates of future events whose outcomes you do not know with certainty until they occur.

WHEN YOU DO NOT NEED ECONOMIC ANALYSIS

A complete economic analysis of even a fairly limited problem can become involved and expensive. Therefore, you do not need an economic analysis when you can show that its benefits are not commensurate with the effort involved.

Example 1-1

Suppose that you take five working days to do a simple economic analysis and you earn $1000 per week for your work. You want to purchase a text formatting system whose total costs are $999. Should you perform an economic analysis?

Solution

No! The economic analysis costs more than the project. If you decide to purchase the system after doing an economic analysis, the total cost is $1999. If an analysis shows that the system is not a sound investment, you spent $1000 to save $999.

Department of Defense (DOD) Directives prescribing alternative replacement criteria or equipment tradeoff standards and legislative action and higher authorities can exempt you from doing an economic analysis.

CHAPTER 2

THE ECONOMIC ANALYSIS PROCESS

INTRODUCTION

The Economic Analysis Process is a systematic, six step procedure for comparing alternative means to meet an objective. You must document the results of your analysis in a written report. In the report, you describe each of the steps and identify pertinent background information, the scope of your analysis, the methodology you used, and your conclusions and recommendations. Appendix A provides a suggested format for this report. Figure 2-1 depicts this process.

ECONOMIC ANALYSIS

THE PROCESS

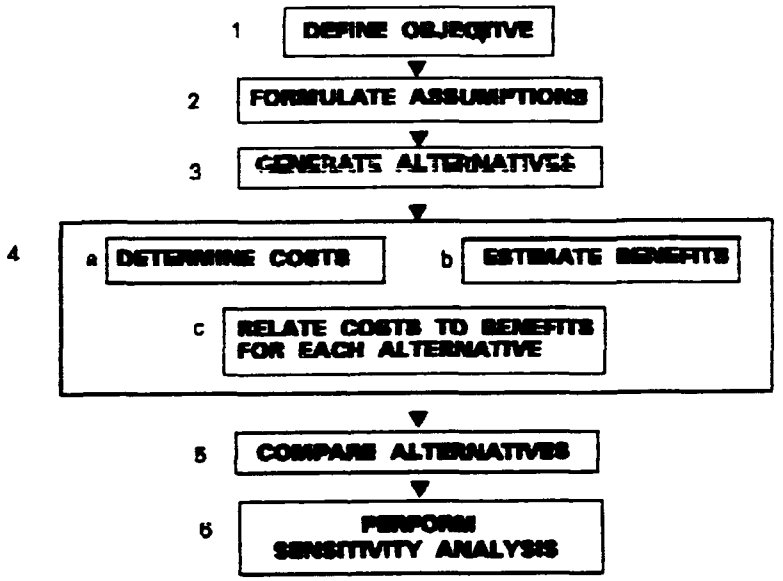


Figure 2-1

DEFINING THE OBJECTIVE

The most important step in the economic analysis process is defining the objective. Most simply stated, an objective is some fixed standard of accomplishment. You should state an objective in terms of a mission or goal. The actual wording of the objective is critical and should reflect a totally unbiased point of view concerning the method of solving the problem. For example, if your goal is to provide a secure, climate controlled working space for electronic equipment with access to utilities, users, and data, state your objective as such. Do not say that your objective is to construct an automated data processing (ADP) center. This might rule out modification of existing facilities or rental of space.

Examples of economic analysis objectives include:

- To process the Mid-Western region ADP work load.
- To improve ADP service at the Naval Air Engineering Center while reducing the cost of ADP.
- To free your main frame computer of all non-command and control applications and provide a 25% surge capacity for crisis and exercise operations.
- To examine the cost effectiveness of installing a System-370 at Newport, Rhode Island.
- To evaluate the economic feasibility of establishing a local area network (LAN) at Norfolk, Virginia.

FORMULATE ASSUMPTIONS

In all phases of government activity, you operate in an environment of restrictions on what you can and cannot do. For purposes of analyses, you present these restrictions as assumptions and constraints.

Assumptions are explicit statements describing the present and future environment that is the base of the economic analysis. Every analyses, no matter how formal or informal, will have assumptions. You simply do not know enough with certainty to avoid making assumptions, particularly when dealing with the future. The purpose of the assumption is not to limit the analysis, but to reduce complex problems to manageable proportions. You must carefully choose and identify all assumptions so that you can realize the basis under which you will eventually develop and evaluate the alternatives.

Four rules to observe in making assumptions are:

1. Don't confuse assumptions with facts. Make assumptions only when absolutely necessary to bridge gaps in essential information you cannot obtain, even after diligent research.

2. Be certain the assumptions are realistic and not mere platitudes or wishful thinking.

3. State assumptions positively, using the word "will". For example, "The ADP system will have an economic life of eight years." "We will have military construction (MILCON) funds in the next fiscal year."

4. Ask yourself if your conclusions remain valid even if you remove one of the assumptions. If yes, then eliminate the assumption. It is not a requirement that you must meet.

Examples of assumptions include the estimated future workload, the estimated useful life of an asset, and the period of time over which you will compare alternatives.

Constraints are factors external to the relevant environment which limit alternatives to problem solutions. They may be time related, as with a fixed deadline; physical, as with a fixed amount of space; financial, as with a fixed or limited amount of resources; or institutional, as with organizational or defense policy and regulations. Whatever particular characteristics they have, these external constraints or barriers are beyond your control. Thus, they provide boundary limitations for alternative solutions to a particular problem.

You must exercise caution when determining assumptions and constraints. An alternative is feasible only when it satisfies all the restrictions you assume. Use of unduly restrictive assumptions and constraints will bias an analysis, precluding investigation of feasible alternatives. Conversely, failure to consider pertinent assumptions and constraints can cause you to recommend a technically or structurally infeasible alternative.

CHOOSE POSSIBLE ALTERNATIVES

Next, you must identify all feasible means of meeting the objective. You must present a comprehensive discussion of the techniques and operational characteristics of each alternative. As a minimum, this discussion should include a description of the method of operation, type of equipment, volume of workload, and any other factors unique to the system. In developing alternatives, you ensure that each alternative addresses the same requirements and that all alternatives satisfy the minimum requirements of acceptability. Later evaluation will reflect the differences in acceptability or effectiveness.

Rarely does an objective have only one alternative. For example, in ADP problems you can almost always consider buy versus lease, manual versus automated, mainframe versus PC, and repair versus replace. Thus, the discussion of alternatives must demonstrate that you explored all reasonable options.

Your search for alternative solutions to an existing problem should not overlook the current system. The current system represents the alternative which seeks to identify the level of costs and benefits which would accrue without changing the present method of operation. If a current system exists and it is feasible, then this system will serve as a baseline with which to compare new alternatives. Note, if you have no current feasible current system, there is no baseline.

Other alternatives which should be considered when evaluating an ADP proposal are:

- o Modifying the current system by modifying existing ADP resources, hiring additional personnel, among others.

- o Acquiring the capability from a Navy Regional Data Center (NARDAC) or from another government agency through resource sharing.

- o Contracting with a nongovernmental source to provide the required capability.

Each method of problem solution has its own mix of resources. While one method requires a multitude of personnel, another may require a large capital investment. Only your creativity and thoroughness limits the number of alternatives.

Sometimes, when you're preparing an economic analysis, you must select alternatives which keep within certain constraints such as manpower, facilities, or funding limitations. You must take care to avoid the imposition of arbitrary constraints which in turn unduly limit the number of alternatives available. Such limitation of alternatives will simplify the analysis, but they do so by excluding other, possibly better, alternatives. Keep in mind that you should not regard as final the list of alternatives you compiled in the beginning of the study. As the analysis proceeds, you may devise new and better alternatives, while you eliminate those not feasible within the constraints.

DETERMINING AND RELATING COSTS AND BENEFITS

In actual practice, the step that is usually the most time consuming and difficult is that of estimating the costs and benefits of each alternative. Most simply stated, costs are inputs, whereas benefits are outputs.

You determine costs and benefits for the entire useful life of a project. You must make appropriate year by year estimates of costs you will incur or benefits you will receive. The difference between the costs of alternatives is most important to you. Omit from the analysis costs which do not change under any alternative and note this exclusion in your assumptions.

Benefits usually are not as easy to identify as costs. However, you should still quantify them whenever possible. You should identify, evaluate, and quantify intangible benefits such as "increased morale" or "increased safety."

You must look into all possible alternatives to ensure that you obtain the best available cost and benefit estimates. Because the acceptance of the analysis depends upon the credibility of the estimates, you must document all sources and derivations of cost and benefit data.

COMPARE ALTERNATIVES

Once you determine costs and benefits for all alternatives, you can make an evaluation of one proposal against another. Usually, you can compare and rank the alternatives according to one of three general criteria. Table 2-1 shows the criteria and the cost/benefit relationship with which it conforms.

TABLE 2-1

GENERAL RANKING CRITERIA

1.	Least cost for a given level of effectiveness	Unequal cost/equal benefit
2.	Most effectiveness for a given constraint	Equal cost/unequal benefit
3.	Largest ratio of effectiveness to cost.	Unequal cost/unequal benefits

If you have alternatives with equal benefits and costs, factors other than economic factors determine your selection.

Table 2-2 summarizes the comparison of alternatives.

TABLE 2-2

COMPARISON OF ALTERNATIVES

Costs	Benefits	Basis for Recommendation
Equal	Unequal	Most benefit
Unequal	Equal	Least cost
Unequal	Unequal	Greatest benefit to cost ratio
Equal	Equal	Not an economic analysis

Note that the first two bases for recommendation are special cases of the third. That is, if all alternatives have the same costs but unequal benefits, then the alternative with the greatest measurable benefits will have the greatest benefit to cost ratio. If all alternatives offer comparable benefits but have unequal cost, then the least cost alternative will have the greatest benefit to cost ratio.

Techniques to evaluate and compare alternatives include:

1. Present Value Analysis. This brings all future cost and benefits back to their present worth. You use this when the economic life of a project is more than three years.

2. Uniform Annual Cost. This is a cost oriented approach to evaluate alternatives with unequal economic lives.

3. Saving/Investment Ratio. This is the relationship between future cost savings and the investment needed to obtain those savings. Because saving is a necessary ingredient, you use this if, and only if, you have a status quo alternative.

4. Discounted Payback. This determines the period that the accumulated present value of the savings require to offset the total present value cost of an alternative. You can use this if, and only if, you have a status quo alternative.

5. Break-Even Analysis. This focuses on the value of a variable (break-even point) where two alternatives equal each other. This seeks to find your point of indifference.

6. Benefit/Cost Ratio. This shows the relationship between output and cost. Use this technique to assess alternatives having unequal cost and unequal benefits.

SENSITIVITY ANALYSIS

You must examine uncertainty in your economic analysis to determine its influence on your recommendation. To test how sensitive your analysis is to uncertainty, you evaluate factors having key relationships to the results of the analysis. You explore the extent and magnitude of their impact.

In performing sensitivity analysis, you determine how the results change with changes in system parameters or basic assumptions. If a change in a parameter or assumption causes a proportionally greater change in the analysis, then it is sensitive to that parameter or assumption.

CHAPTER 3

GENERAL COST CATEGORIES

INTRODUCTION

When you perform an economic analysis, you will encounter various costs. Some costs are relative to your evaluation, other costs have no place in it. You must identify and evaluate all costs for each alternative over its entire life cycle.

LIFE CYCLE COSTS

Life cycle costing follows the principle that your decision to undertake a particular course of action must account for its total cost, not just its acquisition and start up cost. You must account for the cost of developing, procuring, and operating a system. Generally, you find three costs within the life cycle:

1. Research and Development Costs primarily are the costs associated with the development of a new system.

2. Investment Costs are costs beyond the development phase to introduce a new system.

3. Operations Cost are recurring costs of operating, supporting, and maintaining a system.

Figure 3-1 depicts the timing, if not the magnitude, of these costs during the life cycle.

LIFE CYCLE COSTS

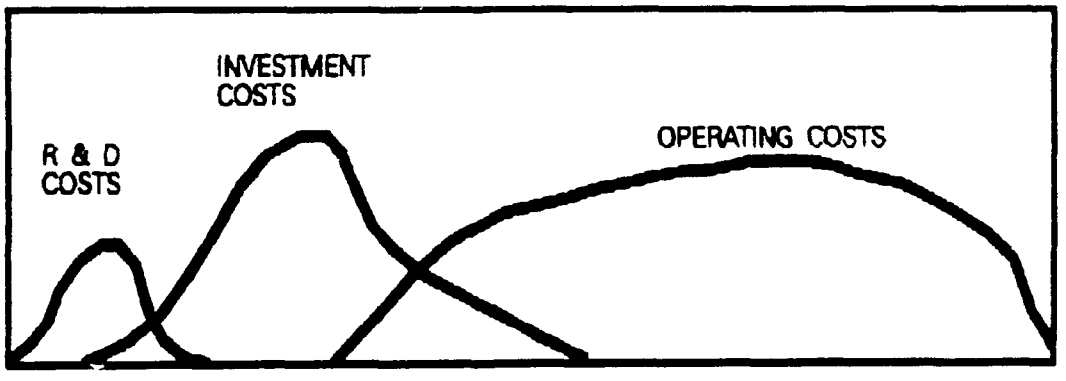


Figure 3-1

OPPORTUNITY COST

Implicit in the discussion of costs is the concept of alternative use. When you use limited resources for a particular purpose, you give up benefits that another alternative could have produced with the same resources. Economists refer to the value of that forsaken alternative as the opportunity cost of employing the resources. You incur opportunity costs when you divert resources already on hand from their current to another project.

Example 3-1

Your boss tasks you to form a team to design a new product. With great confidence in your ability, he tells you to select whoever you need for the project. However, your boss also wants you to tell him what the opportunity cost is for your dream team. You select the following: Worker A, who recently finished a project and now hangs around the water cooler looking for something to do. Worker B, who, like worker A, needs a project but receives twice as much pay as worker A. Worker C, who now works on contract work earning your firm $100 per day. Worker D, who supervises worker C and earns $150 per day for the company. What is the opportunity cost?

Solution

Workers A and B have zero opportunity costs. To employ them on your project, you do not forego any benefit. To employ worker C, you will forgo $100 per day in revenue (benefits). For worker D, you will forgo $150 per day. The opportunity cost for your team is $250 per day.

SUNK COSTS

The principle of life cycle costing applies only to those costs you will incur after you choose an alternative. Life cycle costing only applies to those cash flows that the choice can affect. Costs that you will incur no matter which alternative you choose do not belong in your analysis. They are sunk costs.

Sunk costs include costs already incurred. Your decision concerning future alternatives cannot change costs incurred in the past. Obligations that the law requires you to meet also are sunk costs. When you perform an economic analysis, past costs and mandatory obligations are irrelevant. Do not include them in the analysis.

DETERMINING THE COST OF RESOURCES

Before you can determine the cost of a particular resource, you must first determine if your organization already has the resource available.

EXTERNAL RESOURCES

External resources are any raw materials, labor, equipment, or any inputs to a process that you acquire from an external source. If you do not have a resource in-house, then the cost of the resource is the acquisition or purchase price.

IN-HOUSE RESOURCES

In determining the value of resources that already are in-house, you must determine if your organization currently uses the resource, plans to use it, or if it is surplus.

If the resource is available in-house and your organization already uses it, or plans to use it, for you to employ it in a new use would mean removing the resource from its present or planned use. The cost of using an in-house, already employed, resource is the cost of replacing it, providing a substitute for it, or the costs of the losses you incur by denying it to another project. That is the resource's opportunity cost.

If your organization currently does not use or plan to use the resource, then you could employ it in a new alternative without denying its use to some other in-house purpose. At this point, you must determine a fair value of the surplus resource. If your organization could sell the resource, then the cost of this unused resource is its market or salvage value. But, if you cannot sell, dispose of, or reuse the resource, its cost is zero.

JOINTLY USED RESOURCE

You determine the cost of resources that two projects jointly use on the basis of how much costs will increase if you employ the resource in an alternative project. If the alternative eliminates the joint function, you must determine how much costs will change with the usage of the resource.

NONRECURRING AND RECURRING COSTS

For purposes of the economic analysis, you separate costs into two categories: non-recurring and recurring.

1. Non-recurring Costs obviously are one-time costs. Typically, they include system development, implementation and start up costs. Some may occur during the operating life cycle. Normally, nonrecurring costs include expenditures for investments and all costs associated of equipment, real estate, and nonrecurring services. Nonrecurring cost include:

a. Research and Development (R&D) Costs. These consist of all costs incurred prior to the initial staffing and equipping of a project. R&D costs are costs necessary to design the system and its components and to perform development testing. R&D costs are essentially insensitive to the number

of units of the system that you will procure or the length of time you will operate the system. They usually end once an alternative is ready to use.

b. Investment Costs. These consist of the cost to acquire equipment and real property; nonrecurring services; nonrecurring operation and maintenance (start-up) costs; and other one-time investment costs. Investment costs are a function of the number of units of the system you will procure. The more units you procure, the higher the investment cost. When you identify the anticipated years of incurred costs, you may spread investment costs over several years.

Investment costs include:

(1) Land acquisition or easement.

(2) New construction.

(3) Rehabilitation or modification.

(4) Equipment (ADP and telecommunications).

(5) Software purchases.

(6) System development.
(a) Development of functional requirements.
(b) System design, analysis, programming.
(c) Testing and conversion.

(7) Relocation costs.

(8) One-time personnel costs such as recruitment, travel, relocation, separation, and training.

c. Working Capital is the amount of liquid funds and current assets on hand or on order. Generally, working capital is some form of inventory of consumable or similar resources held in readiness for use or in stock. An increase to working capital requires additional funding. Decreases to working capital reduce the requirement for funding.

d. Value of Existing Assets Employed is the value of assets already on hand that you plan to use with the new project. You include their value in the investment cost only when you currently use the existing assets, plan to use them for an alternative project, or plan to sell the assets. Because you would use or sell these assets, include them at their fair market value and document the basis of this value.

e. Terminal or Residual Value. In many instances, you can impute value to assets that you no longer use. This value can be either terminal or residual. Terminal value, a special case of residual value, is the expected value of buildings, equipment or other assets at the end of their economic lives. You reduce the life-cycle cost of a particular alternative by its terminal or residual value. You may compute residual value of assets at any point in time. Residual value may or may not coincide with terminal value. You apply terminal or residual value to existing assets as you replace them, as well as new assets you acquire. If a proposed project eliminated the requirement for existing assets or property, you will need to determine if they have terminal value. If you redistribute this property to another federal or state agency without direct reimbursement, while that agency benefits, you have no terminal value because you have no reimbursement or cash flow. If you have a documented alternative use for an asset you transfer to another agency, then and only then, can you reduce your investment cost by the fair market value. If you sell the assets, the proceeds benefit your organization or government and set the terminal value.

The terminal value of a new asset is its estimated value at the end of its economic life. Such factors as the probability of continued need for the facility (for Government or private use), appreciation, and depreciation (physical and functional) offset future terminal value. Apply the estimated future value of the asset at the end of its economic life.

What you will do with an asset is probably the most important criterion for determining its terminal or residual value. You need to know if you will scrap the asset, sell it, or re-use it. Will you continue to use it? Each of these situations could call for a different value.

(1) Scrap Value of an Asset. If you are going to scrap an asset, then the only value is the scrap value less costs of dismantling and selling the scrap. Often, scrap values are so small and occur so far in the future that they may have no significant impact on a decision. In such cases, you need not include the terminal value in the analysis. However, if you expect a significant scrap value, then you should include it. Remember to document how you derived the value.

(2) Sale of an Asset. If you are going to sell an asset, the proceeds benefit the Government because the Treasury Department accounts for it as Miscellaneous Receipts. The value you report is the actual sale price less the cost of the sale.

(3) Re-use of an Asset. If you are going to redistribute property to some other Federal Agency, that agency benefits even though you receive no reimbursement for the property. You determine the asset's value by its worth in the market less costs attributed to redistribution.

(4) Continued Use of an Asset. Often, you will need to use an asset for an extended period far into the future. When this occurs, the automatic replacement of assets and repeating cash flows will result in a repetitive cycle of expenditures. You can handle a single project involving multiple assets with different lives two ways.

The first way is to let the economic life of the dominant asset prevail, replacing assets with shorter lives as necessary. The second way uses the shortest economic life and imputes residual value to the asset with the longer life. In this case, you use a pro-rata amount to determine the residual value. Chapter 7, example 7-6 and 7-7, demonstrates this.

2. Recurring Costs, usually called operation cost, are costs you incur on a regular basis throughout the project. They sustain an alternative throughout its life cycle and provide routine support and maintenance. They include all personnel, operating, and overhead costs. They vary directly with the number of units in a program and the length of time you operate, support, and maintain such units. Recurring costs include:

a. Personnel Costs. This is civilian and military costs, employee benefits, and other personnel related costs.

(1) Civilian Personnel Costs. You base civilian personnel costs on current annual salaries as defined by the General Schedule and Wage Board pay rates. Where you identify specific skills with an operation or process, use the middle step of the actual grade in computing wage costs.

(a) Adjustment for fringe benefits. Civil service employees cost the government more than their salaries. This is because they draw fringe benefits. These benefits include the Government's contribution for civilian retirement, disability, health and life insurance and where applicable, social security programs. Customarily, you express the value of fringe benefits as a percentage of annual base pay. Guidance for developing fringe benefits is set forth in Office of Management and Budget (OMB) Circular A-76. The current prescribed rate is 26% and is comprised of the following factors:

Retirement and disability (for employees under Civil Service Retirement).	20.4%
Health & life insurance.	3.7%
Other benefits including work disability, unemployment programs, bonuses and awards.	1.9%

For civilian employees (normally temporary employees) who are not under the Civil Service Retirement System, the Social Security (FICA) cost factor you apply to salary or wage cost is the actual employer contribution rate for the employees involved. When estimating FICA cost, you must ensure that you apply the FICA rate only to wages and salaries subject to the tax. Obtain information regarding FICA tax rates and maximum wages and salaries to which they apply from your personnel office.

(b) Adjustment for Leave. When a requirement specifies a set number for civilian personnel services, this number already includes compensation for sick, holiday and annual leave. However, when a requirement specifies a number of man-hours of work, you use a leave factor to increase the base hours to allow for leave. This is necessary to account for employees on leave. The OMB prescribed leave rate is 18%.

(2) Military Personnel Costs. You base military personnel costs on the current composite standard military rates. Navy Comptroller (NAVCOMPT) Manual, paragraph 035750 identifies these rates. The composite rates provide for the basic pay, incentive and special pay, and certain expenses and allowances included in the active forces military personnel appropriations.

(a) Adjustment for Fringe Benefits. You must adjust the composite rate to include retirement and other personnel costs, such as medical and commissary benefits, that the composite rate does not include. Paragraph 036760 of the NAVCOMPT Manual provides percentage factors for retirement and other costs. The current rate is 25% for officers, 40% for enlisted personnel and is comprised of the following factors:

Retirement Entitlement Accrual rate	
for both officers and enlisted personnel	17%
Accrual Rate for Other Personnel Costs	
for officers	8%
for enlisted personnel	23%

(b) Adjustment for Leave. You apply adjustments for leave for military personnel in the same manner as civilian leave. The prescribed NAVCOMPT Manual factor is 20%.

(3) Other Personnel Related Costs. You should include in other personnel related costs such as travel, per diem, and periodic training.

b. Operating Costs. This category covers operating costs other than labor. Included are:

(1) Equipment rental/maintenance

(2) Space rental/maintenance

(3) Materials and supplies

(4) Utilities

(5) Communications

(6) Commercial services

3. Overhead Costs. You classify some costs as overhead because you can not associate them with specific units of production. Accounting, legal, fire and police protection, custodial services and general administrative costs are overhead. When estimating overhead costs for an alternative, you must take care to itemize only the overhead costs which will change as a result of the investment proposed.

For example, an alternative which significantly decrease personnel needed to provide a service may have no effect on the size of the security force.

PRESENTATION OF COST DATA

Your analysis should contain a description of each cost element and how you derived that figure. For example, if you computed personnel requirements on specific production rates, you should identify those production rates, as well as the numbers and grades of people needed.

Once you have discussed all costs, you should present them in a manner which will allow the decision maker to easily review the data. You should consider the costs on a cash-flow basis for each year, identified by category; nonrecurring or recurring. Figure 3-2 shows a sample format for presenting costs.

UNDISCOUNT COSTS
ALTERNATIV No. __

COST ELEMENT	FY 0	FY 1	FY 2	FY n
1. Non-recurring Cost a. ADP Equipment(ADPE) b. Site Construction c. System Development d. Telecommunications e. Travel				
2. Recurring Cost a. ADPE Maintenance b. Personnel c. Space Rental d. Supplies e. Telecommunications				
TOTAL COST				

Figure 3-2

CHAPTER 4

INFLATION

INTRODUCTION

To make an economic analysis a useful decision making tool, you must accurately estimate future costs and benefits. When prices persistently and appreciably rise over time, projecting costs with precision is more complicated. Fortunately, the economic analysis process and the standard 10% discount rate implicitly resolve the issue of inflation so that you do not need to be overly concerned about the effect of inflation in your analysis. Moreover, explicitly introducing inflation into your analysis usually has no effect in the final ranking of your alternatives. With this in mind, the remainder of this chapter explains some of the problems that inflation causes and how the economic analysis process and you handle these problems.

TERMS TO KNOW

Before you can manipulate inflation and account for its effects in you analysis, you need to understand a few of the most basic terms.

1. Inflation is a general rising level of prices. This does not mean that a rising price for a single product is inflation. Nor do all prices necessarily rise during periods of inflation. In fact, a major problem with inflation is its unpredictability.

2. Changes in Demand are shifts in the desirability of a product in the market place. Given a set supply, an increase in demand for a product results in a shortage in the market, leading to higher prices. This does not represent inflation.

3. Changes in Supply are shifts in the quantity of a product in the market place. Given a set demand, an decrease in supply for a product results in a shortage in the market, leading to higher prices. This does not represent inflation.

4. Changes in Price are shifts of the supply demand equilibrium point, as noted in 2. and 3. above. This shift does not represent inflation.

5. Base Year Dollars are the value of dollars after you adjust them for inflation.

6. Current Dollars are costs and monetary benefits reflecting the actual amount you pay including any amount due to future price changes.

7. Base Year Prices are prices in effect at the beginning of an analysis and prices after you adjust them for inflation.

PROBLEMS OF INFLATION

You may readily associate several problems with inflation. Perhaps you note that things cost more today than they did years ago. Maybe you see that a dollar simply doesn't buy as much as it use to. Whether this is a real problem depends on whether your budget automatically adjusts itself to reflect inflation, or if you have to determine the rate of inflation and then request more money, or if you have a fixed budget.

If your budget adjusts itself to the inflation rate, then inflation is mute. That is, given that this year's rate of inflation is 10 percent, your budget automatically will include a 10 percent adjustment for inflation. While prices rise, you have more money to buy these goods.

However, if you must determine the rate of inflation and then request an adjustment, or if you have a fixed budget, you encounter another aspect of inflation. That is, while you note that today's prices are higher and a dollar doesn't purchase as much as before, you don't know how much more future prices will rise or how much less a future dollar will buy.

This uncertainty complicates financial planning and economic analysis. Determining the rate of inflation and projecting the increase in prices and decrease in buying power would eliminate some of your uncertainty and some of the complications.

Example 4-1

This year you have $100 in your budget to purchase mechanical pencils that cost $1 each. Normally, you buy 100 pencils. Over the course of the year, the inflation rate is 10 percent. Assuming your budget adjusts itself for inflation and that pencils also keep up with inflation, how much money will next years budget have for pencils and how many fewer pencils can you purchase? If you need 100 pencils next year, what other purchase will you reduce to have money to buy the pencils?

Solution

Since your budget automatically adjusts itself for inflation, and inflation was 10 percent, your budget will have 10 more dollars slated to purchase pencils. Thus, your new pencil budget is $110. Assuming that pencils kept up with inflation, they will cost 10 percent more, or $1.10 each. Thus, you can buy exactly 100 pencils, the same as the year before. You forego nothing.

TREATMENT OF INFLATION IN COMPUTATIONS

The accurate treatment of inflation requires a two phased approach. Within the Department of Defense and Department of the Navy, DOD Instruction 7041.3, and Secretary of the Navy (SECNAVINST) 7000.14B require this treatment of inflation in economic analyses.

1. Perform the analyses in terms of constant dollars. Make all estimates of costs and savings during the project life in terms of base year prices. This requires that you assume a rate of inflation.

a. Change cost projections to reflect only real changes in costs due to changes in amounts of services and improvements.

b. Change cost projections due to changing economies of scale due to an increase or decrease in the quantity of goods and services.

2. Determine the present value of the cash flows. Chapter 8 discusses present value in detail.

a. Avoid overestimating and double counting for the effects of inflation. Consider such factors as labor agreements and contract provisions that may include provision for inflation, productivity and quantity changes, and the extent of material already on hand or obligated under fixed price contracts.

b. Whenever practicable, estimates will include forecasts of changes in price levels on the basis of specific data applicable to a given acquisition. As part of the analysis, include the source of the inflation factors and the rates used.

c. Identify the estimates of inflation by fiscal year. Take particular care when including inflation in cost estimates for more than four years beyond the budget year. Forecasting future national economic conditions and factors for inflation involves uncertainty and are subject to considerable change.

The requirement to perform your analysis using constant dollars promotes consistency in your comparison of alternatives. As Chapter 9 discusses, the standard 10 percent discount factor implicitly escalates your cost estimates to reflect inflation. Thus, your economic analysis, at the 10 percent rate, should suffice in most cases. Again, introducing inflation factors into your analysis usually has little effect in the final ranking of your alternatives.

STEP 1 **Raise out-year costs to NOMINAL levels by expected inflation rate, I.**

Example 4-2

Assume an expected inflation rate of 5% which is called rate I. Then I = .05. Raise each out-year cost figure by 5%.

Year 0 costs do not get raised.
Year 1 costs are multiplied by 1.05
Year 2 costs are multiplied by $(1.05)^2$
Year 3 costs are multiplied by $(1.05)^3$
Year n costs are multiplied by $(1.05)^n$

Out years:	0	1	2	3
Uninflated costs:	1000	1000	1000	
Inflation factor:	1	1.05	1.102	1.158
Inflated costs:	1000	1050	1103	1158

STEP 2 **Calculate nominal discount rate, D.**

Example 4-3

The nominal rate D includes the DOD discount rate of 10% (which we call R) plus inflation at rate I.

$$D = (1 + R)(1 + I) - 1$$

Example 4-4

Assume a DOD 10% rate combined with I, the 5% inflation rate.

$$D = (1.1)(1.05) - 1$$
$$D = (1.155) - 1$$
$$D = 15.5\%$$

STEP 3 **Plug D into discount factor calculation.**

Discount factor = $(1 + D)^{-n}$

Example 4-5

Year 0 discount factor is $(1.155)^{-0} = 1$
Year 1 discount factor is $(1.155)^{-1} = .866$
Year 2 discount factor is $(1.155)^{-2} = .750$
Year 3 discount factor is $(1.155)^{-3} = .649$

STEP 4 **Combine nominal out-year inflation of costs with nominal rate of PV calculation.**

Basic discount: 10%. Projected inflation rate: 5%. Discount rate with inflation: 15.5%

Out years:	0	1	2	3
Uninflated costs:	1000	1000	1000	
Inflation factor:	1	1.05	1.102	1.158
Inflated costs:	1000	1050	1103	1158
Year-end discount factor:	1	.866	.750	.649
PV of costs:	1000	909	826	751
Cumulative PV of costs:	1000	1909	2736	3487

PV of project: $3,487

We have inflated out-year costs and calculated their PV with an inflation-adjusted discount factor. Compare that project PV value with the project PV that is calculated for the same out-year costs without inflation.

Out years:	0	1	2	3
Projected costs:	1000	1000	1000	1000
Year-end discount factor:	1	.909	.826	.751
PV of costs:	1000	909	826	751
Cumulative PV of costs:	1000	1909	2736	3487

PV of project: $3,487

Voila! The PVs of both projects = $3,487. Calculations for expected inflation have no effect on the comparative project PVs. Accounting for inflation affects the increased out-year costs and the adjustment to the discount rate by the same percentage.

NOTE: If mid-year discount factors had been used instead of year-end factors, the PVs for the two projects would have been close but not exactly the same.

Does this mean you can ignore inflation in economic analysis? Yes. However, make sure that you are consistent. If you ignore inflation in out-year costs, then do not adjust for inflation in your discount rate. If you do take account of inflation in out-year costs, then you must adjust for inflation in your discount rate.

Which should you do? Using real values and a real discount rate is usually better. You typically will have better data on real cost increases then you will have on an expected rate of inflation. Predicted inflation rates, even by experts, are often wide of the mark.

Keep in mind that not all projected increases in out-year costs are inflationary. For example, you might have rising out-year costs for labor that are the result of a wage contract settlement. The settlement, itself, may reflect local shortages of skilled people such as programmers.

Nonetheless, the same discounting calculations would be used. If the wage settlement raised labor costs by 7%, you would boost out-year labor cost projections accordingly. But do not add a 7% premium to the DOD 10% discount rate. The reason: the 7% rise is a real increase. You adjust the DOD rate only when you are dealing with costs as a consequence of inflation.

Suppose that, as part of an economic analysis, you receive cost data that show out-year increases. You are not told whether these increases are nominal (due to all prices in the economy rising) or real (due to supply and demand in a specific market). The source of the data may not know. You must make a judgment call. A quick-and-dirty way to distinguish nominal changes from real ones is to compare the annual percentage change in the out-year costs to the current annual percentage change in the Consumer Price Index (CPI).

If projected out-year costs are rising at a rate close to the current CPI, you are looking at nominal (inflation-driven) changes. If the cost estimates are rising at a rate that is obviously different from the CPI, then you can assume that they are not driven by inflation. They are real changes.

CHAPTER 5

COST-ESTIMATING TECHNIQUES

INTRODUCTION

The adequacy or success of costing efforts primarily depends on your ability to establish relationships between the attributes and the elements of a proposal. That is, the relationship between *the requirements of an alternative and the costs of these requirements. Cost estimating techniques* depend upon such factors as the amount and detail of available data and the time and resources available to develop the cost estimate. This chapter discusses four cost estimating techniques: industrial engineering, parametric cost estimating, analogy and Delphi estimating. The level of effort and knowledge you need in order to use these procedures ranges from intuition to extreme detail.

INDUSTRIAL ENGINEERING METHOD

The industrial engineering method consolidates estimates from various separate work segments into a total project estimate. You may call this the "bottom up" process because it involves the separation of the total end product (whether hardware or software into simple parts for which you can establish detailed estimates. For example, the estimated cost of producing a new model "widget," requiring work contributions from 10 separate work divisions, could be a summation of 10 separate detailed estimates. Each of the estimates could have several estimates in their own right.

You use one or more of the following to develop the detailed estimate for each of the work contribution areas:

1. Examination of historical data for similar items.
2. Reviewing current operations (using industrial engineering techniques such as work measurement, time and motion studies, sampling) and establishing new standards.
3. Engineering simulation of operations required to produce the item.

The end result is the consolidation of the individual estimates into a total projected cost for the alternative.

An advantage of this method is that it separates the parts of the system on which little data are available and permit them to receive special treatment. The industrial engineering approach can result in extremely detailed and complete estimates of alternative costs. Where detailed data exist, the industrial engineering method is the best method for estimating costs.

PARAMETRIC COST ESTIMATING METHOD

When you do not have adequate data to employ the industrial engineering approach, you may turn to the parametric cost estimating method. This method compares uses an object of known or estimated value to draw conclusions about the cost of an alternative. The results of a parametric estimate depend directly upon your ability to establish relationships between the parameters of the known object and it's cost, and the alternative's parameters and it's cost.

This method concentrates on what the proposal should accomplish. The yield or benefits of the proposal form the bases (or "parameters") for the cost estimates. Once you establish the bases, you seek a relationship between the parameters and their costs. Generally, you develop the relationships from historical data. If you use a single experience for data, the extrapolation to the proposal may be questionable. This data foundation becomes firm as experience with similar systems increases.

Inasmuch as past experience forms the bases for parametric estimates, you include costs due to problems inherent in system development. To resolve questions regarding unanticipated delays due to technical problems, redefined requirements, and midstream changes, you include these expenses in the historical data.

The primary limitation of parametric costing lies in the cost data that are available. Also, as the variation of new systems from previous systems increases, the credibility of the estimate decreases. Parametric cost estimating is the preferred procedure to use in deriving a cost estimate at the earliest stages of development. At this time, you can only base the system cost on expected physical and performance characteristics and their relationship to costs.

Example 5-1

Suppose a family contemplates purchasing a new house. Among the requirements they have for the house are:

Number of bedrooms (2, 3, 4 or more).

Number of baths (1, 1-1/2, 2, 2-1/2 or more).

Number of dens (0 or 1).

Number of finished family rooms (0 or 1).

Capacity of the garage (0, 1, or 2 cars).

Size of property lot (in acres).

Age of the house (in years).

Solution

If they know the selling price for a house with any particular combination of these parameters, for example, the expected selling price of the house they currently occupy, then they may estimate prices for other parameter mixes relative to this baseline.

ANALOGY METHOD

When you have no qualified cost analysts and little historical data, the entire effort becomes an application of judgment. A special method of judgment is the use of analogies. An analogy is a direct comparison with similar, historical alternatives. A major caution with this process is that it is essentially a judgment process, requiring expertise and intuitive reasoning. Although this is a widely used method of estimating costs, it is not the most accurate.

There are two types of analogies: similar products and similar concepts. Using commercial aircraft costs to estimate the cost of military aircraft is a similar product analogy. Using aircraft costs to estimate missile costs is a similar concept analogy.

DELPHI METHOD

The Delphi method is a way of using expert opinion to arrive at a forecast or estimate by subjecting the views of the individual experts to each others criticism in ways that avoid face to face confrontation and provide anonymity of opinions and arguments in defense of these opinions.

In one version of this technique, you replace direct debate with the exchange of information and opinion through a carefully designed sequence of questionnaires. You ask the participants to give not only their opinions but reasons for these opinions, and at each successive interrogation you give them new and refined information, in the form of opinion feedback, which you derive by computed consensus from the earlier parts of the program. This continues until additional progress toward a consensus is negligible. You then document the conflicting views.

The disadvantage of this technique is that it is cumbersome. Several weeks may elapse before the participants return their questionnaires or you can poll them. The amount of material you must process for each respondent for each round may be considerable, and because of the lapse of time the respondent may have difficulty reproducing his earlier reasoning. Finally, Those who are running the process have their own difficulties with digesting and collating a formidable amount of material.

CHAPTER 6

BENEFIT QUANTIFICATION

INTRODUCTION

Benefits are outputs expected from costs incurred. In this usage, benefits are synonymous with results, effectiveness, utility, or performance. Because costs relate to inputs, not outputs, you do not consider a reductions in costs as a benefit. Benefit analysis presents an comprehensive, meaningful, and orderly display of all returns expected, for each alternative. Benefits are more difficult to quantify than costs. This is because some benefits seem intangible. Some benefits have no simple common denominator such as dollars. If no common denominator is available, rank the benefits according to a hierarchy of values so that you can make a more rational choice.

Conduct a benefit analysis with a basic three step method:

1. Determine, list, and define the relevant benefits.

2. Identify the sources of information.

3. Devise a system for measuring the benefits.

In addition to benefits, include and quantify information concerning any negative aspects of alternatives. Such information could be the environmental, social, personal, and legal impact of the alternative. This information is important and may be a determining factor in deciding between possible investment alternatives.

STEP 1. DETERMINE, LIST, AND DEFINE RELEVANT BENEFITS

This step involves naming the benefits for each alternative, whether you think them quantifiable or not. List all benefits which may shed light on the economic analysis alternatives. Eventually, you may discard some of them while others may become evident later on. Nonetheless, give a full description of each benefit.

You may place the benefits expected of any alternative into various categories depending upon the kind of program, system, operation, or organization you are analyzing. The terminology you use for these categories is generally descriptive of the benefits included. Following is a guide to categories you can use. It is not all inclusive. Rather, it illustrates some categories you could apply. They are:

1. Production. This is the number of commodities or items produced for each alternative. For example, number of meals served or components manufactured. You could state this in comparable time periods for the economic analysis.

2. Productivity. This is the number of items produced per man-hour.

3. Operating Efficiency. This is the rate at which the system consumes resources to achieve its output. For example, gallons per mile or copies per kilowatt hour.

4. Reliability. This is the system's probable failure rate. Useful measures may be mean-time-between-failure, service calls per year, or percent refusals per warehouse request.

5. Accuracy. This is the system's probable error rate. Useful measures may be errors per operating time period, such as errors per card punched, errors per hundred records, errors per 100 hours of operation time.

6. Maintenance and Control. Did the system developers do adequate human engineering? Can adequately trained workers effectively use the system? When the system fails, is it difficult to repair because of poor accessibility? You could base useful measures on the average number of man-hours necessary for repairs over a given time period, "downtime," or the work force required to control and maintain the system.

7. Manageability. Will implementing the system increase or decrease supervision or inspection time? Useful measures may be man-days, the difference in the kind of personnel or the availability of the type of personnel needed.

8. Integration. How will future changes in the system, such as modification of existing facilities or equipment, technical data requirements, initial personnel training, or warehouse space for raw goods or parts storage affect the workload and product of the organization? Will data from your previous system be compatible with the new system? What about programs developed for tour previous system? What about supplies such as printer ribbons, paper, cards, and in.

9. Availability of Equipment and Supplies. This is when you can deliver or implement the alternatives. You need to consider proposed output schedules and lead time for spare parts delivery, among others.

10. Service Life. This is how long the proposed system will affect the organization's workload or output. Remember to consider obsolescence?

11. Quality. Does an alternative provide a better quality product or service? Can you grade quality? If not, can you describe the improvement? What is the impact of varied quality?

12. Acceptability. Will the alternative interfere with the operation of parallel organizations or the operation or prerogatives of higher echelon organizations.

13. Environmental. Consider the environmental aspects of each alternative. What are current legislative requirements?

14. Economic. Consider employment benefits, DOD small business obligations, economically depressed area relationships, legislative requirements.

15. Morale. Will the alternative affect employee morale? Can you measure this as a reduction in sick leave days?

16. Safety. Will the alternative change the expected number of accidents or other hazards involved?

17. Security. Is security built in? Will this alternative require more precautions? More guards? Are thefts more likely?

Table 6-1 is an example of one analyst's initial listing of benefits. In this example, the analyst compared contracting a computer programming requirement to an established programming firm vice establishing a new in-house capability.

TABLE 6-1

BENEFITS

	CONTRACT		IN-HOUSE
1.	Fewer programming errors.	1.	Quick debugging if required.
2.	No training required.	2.	Shorter turnaround time.
3.	Known costs.	3.	Easier communications.
4.	No equipment maintenance nor logistic support.	4.	Decreased transmittal effort.
5.	Fewer personnel problems.	5.	Immediate availability once established.
6.	Increased experience and capacity for future expanded effort.	6.	Improved management control.
7.	Greater capability to manage varying work.	7.	Provides training capability.
8.	Avoid difficulties of recruiting during a programmer shortage.	8.	Increased understanding of agency problems.
9.	No costs if product does not meet specification.	9.	Greater ability to change direction of mission.

STEP 2. IDENTIFY SOURCES OF INFORMATION

For each benefit listed, identify: (1) The source of information, (2) in what form is the information available, and (3) if gathering the information is feasible, how can you gather it? Sources of information should apply to benefits which may be quantifiable as well as those which do not seem quantifiable.

STEP 3. DEVISE A SYSTEM FOR MEASURING BENEFITS

The third step is to devise a method to measure the output of each alternative. Such measurement can vary from precise quantities of physical output for the more tangible benefits to general narrative descriptions for intangibles outputs.

QUANTIFIABLE OUTPUT MEASURES

An economic analysis is most effective when you can define output in terms of physical yield. Each analysis will possess its own measure of effectiveness. In fact, an analysis may contain a number of different measures. For example, you could state reduced pollution in some quantifiable terms, such as gallons of effluence per hour. You might state decreased procurement lead time in days or in changes in inventory levels. In citing increased safety as a benefit, you could state the number of employees exposed to the dangers for each of the proposed alternatives.

If you cannot precisely quantify the benefits, you may be able to establish a relationship among the alternatives. You may express the benefits of one alternative in the form of an index and relate the benefits of another alternative to that index.

As quantification of benefits becomes less feasible, you must rank the alternatives on a more subjective basis. This may consist of simple numerical listing in order of preference, with the alternative's position in the list not indicating any particular level of benefits. Or you may use a verbal scale describing the alternatives by using adjectives to indicate their relationships as excellent, good, or poor. These measurements are useful but less precise objective measurements.

NON-QUANTIFIABLE OUTPUT MEASURES

Despite your best efforts to develop quantitative measures of benefits, you sometimes face a problem which simply does not lend itself to easy quantification. Certain projects may provide only intangible benefits such as improved morale or better community relations. Although they are more difficult to assess, you should document and include these benefits in your analysis.

In these instances, use written, qualitative, benefit descriptions and the following guidance:

1. Identify all benefits attendant to each alternative under consideration. Give complete details.

2. Identify benefits common in kind but not in extent or degree among alternatives. Explain differences in detail.

3. Avoid platitudes. All prospective projects should support your mission. Do not restate this. Platitudinous statements cloud the decision making environment.

BENEFIT ANALYSIS PITFALLS

Some consider benefit quantification to be the weakest area in most economic analyses. To strengthen your analysis, avoid the most common pitfalls.

First, do not confuse benefits and cost savings. This error has a history of occurrence in ADP analyses, probably because ADP people think of their systems as a means of cutting costs. Cost savings is the difference in cost between alternatives. You reflect cost savings in the differential cost of alternatives and you may use it as a basis for decision between alternatives. However, do not confuse cost savings with the output, product, or benefit of alternatives. Cost savings do not belong on the benefit side of the equation.

Benefits should reflect an organization's basic mission. The benefit or output of a system must support that mission. Accordingly, if cost savings were a benefit, then cost savings would be the reason for the existence of a system. How could you save the greatest cost of the system? Eliminate the entire system! Clearly, you must find the benefit in the product or service of the ADP system.

Another common, possibly deliberate, error is the "equal benefits" escape clause. One way of avoiding the problem of benefit measurement is to assume that benefits are equal and use least cost analysis. To establish equal benefits, you must be indifferent to the benefits of the alternatives.

If you are not indifferent, because the alternatives offer significantly different benefits, the least cost recommendation also fails to support itself.

An example of this problem is the argument that an analysis is faulty because it always recommends a modified or rebuilt system instead of the development of a new system. If two alternatives offer equal benefits in terms of production rate, reliability, and responsiveness, the analysis is quite proper in recommending a modified or rebuilt system. However, if you can show that the new system offers a significant upgrade of capabilities, the least cost criterion is at fault. Use of the unequal cost/equal benefit criteria would enable you to identify the increased capability and the cost of such increase. Then, you evaluate increased cost against increased capability.

Another error is to use spurious measures of benefits. In searching for something to count, measure, or record, you may measure ancillary or independent activities because they have a tangible, easily identified product. For example, you may measure the "productivity" of the night shift workers based on CPU utilization or the "effectiveness" of a programmer based on number of lines od code produced.

Spurious measures are dangerous for several reasons. First, they do not necessarily measure the output you needed to measure. Second, once you highlight and use other activities as a performance measure, they can dominate your analysis. Third, once your workers realize how you grade their performance, they perform to increase their score based on the spurious measure.

Another error is the omission of quality control. An unequivocal description or a set of specifications is necessary, to ensure that you do not increase productivity or decrease costs at the expense of quality and usefulness. For example, making an inferior product with fewer inputs.

The final error is quantification at any cost. Valid methods to measure almost all benefits exist, if you can justify the resources required for the task. Quantification is useful. But you should seek it within the parameters of resources, validity, and accuracy. Inaccurate quantified measures can do more harm than good and may lead to poor decisions.

CHAPTER 7
ECONOMIC LIFE AND PROJECT LIFE

INTRODUCTION

Chapter One defined economic analysis as a decision tool. A fundamental decision you personally or managerially make each day is whether to spend more money today and less tomorrow or less now and more later. A rational choice means that you must determine how far into the future to extend the expenditure. You must set the appropriate time period of the economic analysis. Once you do this, you can develop cost streams for each alternative.

ECONOMIC LIFE

Economic life is the reasonable period of time over which you expect a project to accrue the savings or benefits. Three factors ultimately govern economic life:

1. The Mission Life is the period over which you anticipate a need for the asset or program. For example, a college freshman decides to purchase a personal computer to use for assignments at school. He anticipates that he will need the computer only during his remaining time in school. Thus, the mission life of the computer is four years.

2. The Physical Life is the period during which a facility or piece of equipment is available for use before it wears out in a physical sense. The physical life of an asset may vary depending upon usage, manufacturing quality, and the age of the asset when you first place it into production. For example, the college freshman compared the prices of new and used computers. According to a computer magazine he read, the internal components of a PC should last eight to ten years, given normal use. Thus, a new computer has a physical life of eight to ten years, while a used computer would have the same, less its previous ownership.

3. The Technological Life is the period you can use an asset before improved technology makes the asset obsolete. A computer remains technologically viable as long as you can enter and retrieve data from it in a usable form, provide required maintenance, and use it productively. As the use of key punch cards and batch systems show, the ability to interface with a computer often lingers on long for many years. However, with rapidly changing technology, the technicians who maintain your equipment will become scarcer as they move onto newer systems. Additionally, as your system ages, you will have to convert the format of more data from external sources. In this manner, the efficiency of the computer degrades. Thus, for computer systems, the ability to provide maintenance and use the asset productively most often define the end of technological life.

Usually, economic life is the shortest of the technological, mission, or physical lives. Also, you should not project economic lives in excess of 30 years due to planning horizon limitations. Due to discounting, cost streams beyond 30 years have little effect on decisions.

CASH FLOW DIAGRAMS

You can depict life cycle costs through the use of cash flow diagrams. A cash flow diagram is a pictorial technique for representing the magnitudes and timing of costs associated with an investment alternative.

Customarily, you draw cash flow diagrams for each alternative in the economic analysis. Draw a horizontal line to illustrate the entire project period. Divide the line into equal time periods and number each period chronologically. Use the up arrow ↑ to illustrate cash inflows (receipts) and down arrow ↓ to represent cash outflows (costs).

NOTE: While this manual represents the cash flows as if they occurred at the end of each year, it assumes that they occurred throughout the year.

Example 7-1

Suppose a project has an economic life of six years. You spend $10,000 for equipment and $2,000 per year for maintenance. At the end of year six, the equipment has scrap value of $1,000. What does your cash flow diagram show?

Solution

Your initial investment of $10,000 occurs at "time zero" (right now). Costs of $2,000 occur each year. At the end of the sixth year, receipts of $1,000 represent the terminal sale value. Figure 7-1 shows your cash flow diagram.

CASH FLOW DIAGRAM

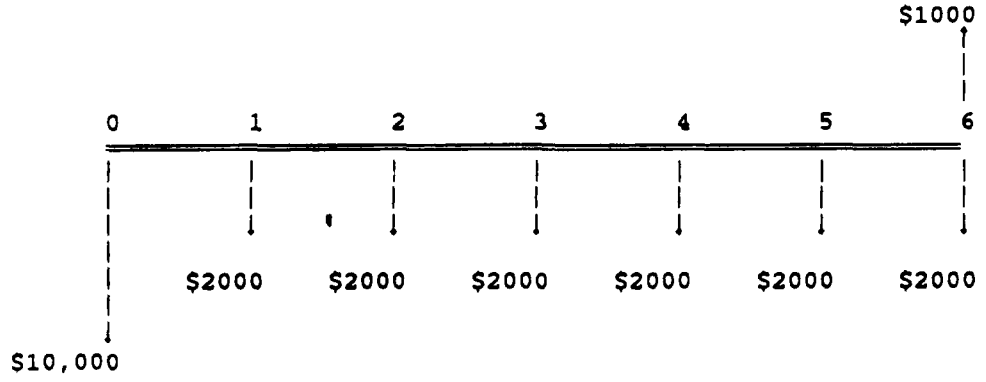


Figure 7-1

The difference between "Year 0" and "Year 1" can be confusing. Figure 7-2 explains the meaning of these terms.

LEAD TIME AND PROJECT LIFE

Investments sometimes occur several years prior to the time that the project starts providing benefits. The time between initial funding of the project and the commencement of the economic life is "lead time". The lead time together with the economic life is the project life. When you consider lead time as part of project life, you must alter the cash flow diagram.

CASH FLOW DIAGRAM

YEAR 0, YEAR 1 EXPLANATION

Year 0 represents the start of the project. For example, in years, how old is brand new equipment when you first buy it?

Year 1 represents the first "birthday" of the project. It marks the passing, not the beginning, of the first year.

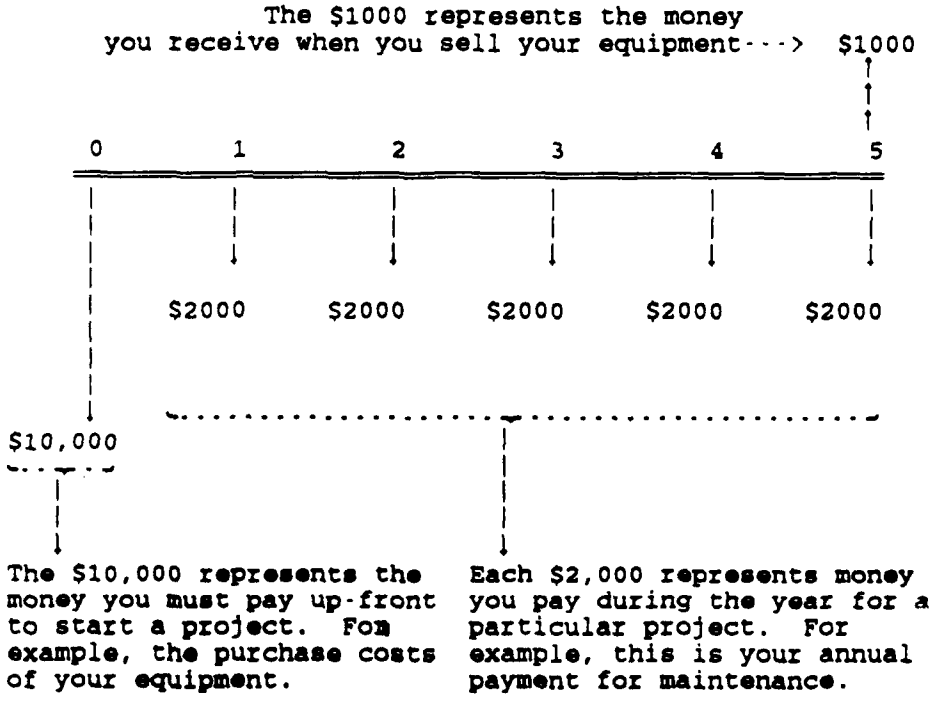


Figure 7-2

Whether you should include money spent during the lead time depends on the control you have over the money. If you have no control over whether you spend the money, do not include it in your analysis. Consider it a sunk cost. On the other hand, if your selection of an alternative changes the amount of money you spend, you must include it in your analysis.

PERIOD OF COMPARISON

Once you ascertain the economic and project lives of each alternative, you must determine over which period to compare the alternatives. Normally, set the time period for the comparison so all alternatives start yielding benefits during the same year.

Because economic lives and lead times can vary among alternatives, DOD has established the following guidelines for determining a period of comparison:

1. Same Economic Lives and Lead times. If the economic lives and lead times for all alternatives are the same, compute alternatives over the same project life.

2. Same Economic Lives/Different Lead Times. If alternatives have the same economic lives, but different lead times, consider the first year with cash outflows as the base year or "project year one" for all alternatives.

3. Different Economic Lives. When the economic lives of the alternatives are different, you can handle the problem several ways. The first is to let the asset with the longest economic life prevail while replacing other assets as necessary. The second method is to use the shortest economic life and impute residual value to the asset with the longer life.

A third method of comparing alternatives with unequal economic lives is to use the Uniform Annual Cost technique. This cost-oriented approach puts life cycle cost and receipts for each alternative in terms of an average annual expenditure. Chapter 11 details this method.

CHAPTER 8

THE NOTION OF PRESENT VALUE

INTRODUCTION

As with other goods and services, money is a marketable commodity. You can buy and sell money in the marketplace. Generally, "goods or labor" is the purchase price of money.

"Interest" is the rental charge for money. You can explain the existence of interest by examining both the supply and the demand for money. By loaning money to another, you remove it from your available funds. In doing so, you deprive yourself of immediate satisfaction, that is, you cannot use this money to buy consumer goods now. For example, you make a sizable loan to a friend. While he has the money, you must delay your purchase of a new television, car, bass boat, or vacation.

Interest, the rent your friend pays to borrow your money, is your motivation to make the loan. The greater the fee or the higher the interest rate, the greater the motive to delay consumption in order to earn a return on invested money.

On the borrowing side, it is sometimes profitable for businesses to borrow money and pay the interest. This is because capital goods such as engineering equipment, machines, and structures return more income than they cost. Likewise, it is rational for government activities to pay interest on money invested in equipment that saves annual operating costs or improves service.

SIMPLE INTEREST

In order to understand the meaning of present value, you must understand how interest functions over time. Customarily, you express the interest rate as a percent or decimal, representing the fractional amount of a loan the borrower must pay the lender within a specified interval of time. To determine the amount of interest (I), you multiply the principal (P) by the rate of interest (i). You express this simple interest formula:

$$I = P * i$$

Additionally, if you borrow an amount of money (P) today at an annual interest rate i, at the end of the year you will have to return to the lender not only the original amount P but also the interest (I). Thus, the total future amount due (F_1) is:

$$F_1 = P + I$$

$$= P + (P * i)$$

$$= P(1 + i)$$

Example 8-1

Suppose you borrow $1,000 at an interest rate of 6%. What is the amount due to the lender one year from now?

Solution

$P = \$1{,}000 \qquad i = 6\%$

$F_1 = P(1 + i)$

$F_1 = \$1{,}000 * (1 + .06)$

$F_1 = \$1{,}000(1.06) = \underline{\$1{,}060}$

COMPOUND INTEREST – THE FIRST YEAR

You calculate interest and principal for most accounts on a compound basis. Compound interest results from adding interest to principal in each period before calculating the interest on the new principal for the next period.

For example, you borrow $1000 at six percent interest, compounded annually. If you pay no principal the first year, at the end of the year you owe $1060. That is $1000 of the principal plus $60 of interest. At this point, your interest formula is the same as the simple interest formula: $I = P * i$. The amount due is: $F_1 = P(1 + i)$.

COMPOUND INTEREST – THE SECOND YEAR

Suppose that from the example above, you borrow money but make no payments for the first two years. Again, at the end of the first year, you owe $1060. However, at the end of the second year you owe $1123.60, not $1120. The $3.60 difference is the effect of compounding. That is the original $1000 and its $60 of interest (1060), plus $63.60 interest on $1060 in the next year.

The amount you must pay at the end of year two (F_2) becomes:

$$F_2 = P(1 + i) + i(P(1 + i))$$

$$= P(1 + i)(1 + i)$$

$$= P(1 + i)^2$$

COMPOUND INTEREST – n YEARS

The difference between the expression for one year and two years is the addition of an exponent. You can show through successive repetition of the above reasoning that if you borrow an amount P today at an annual interest i, the total amount owed to the lender, F_n, at the end of n years is:

$$F_n = P(1+i)^n$$

THE CONCEPT OF PRESENT VALUE

Time effects the value of money. If this is not readily apparent to you, imagine that you just won a sweepstakes and the prize is millions of dollars. The sweepstakes official calls to tell you the good news and asks one more question. "Do you want to receive the millions of dollars this Monday, or do you want to receive it ten years from now?"

Most people would rather have the money today. If you have the money today, you can buy food, shelter, and clothing. If you have the money today, you can invest it and expect to earn more money. If you have the money today, you have it. Can you be sure that you or the lottery official will be here in ten years?

That banks pay interest on deposits, that people, businesses, and government pay interest on loans, this should tell you that money is worth more today than the same amount a year from now. This has nothing to do with inflation. Banks pay interest even during periods of falling prices. Utility, opportunity cost, and uncertainty ensure that you value money in your hand more than money you might receive later on.

Thus, if you have a choice of receiving money now or ten years from now, there is little question of your preference. By accepting the money now, you could, through careful investment, have much more money in ten years.

The reverse of this principle applies to outflows of cash. Obviously, you would rather pay out $1,000 ten years from now than pay out $1,000 now. Because of this time value of money, you must adopt some procedures to evaluate <u>future</u> cash flows in terms of <u>today's</u> money. You call this the present value of the money you expect to receive or spend in the future.

Economists and accountants recommend a common time basis adjustment known as discounting. Discounting is the reverse of compounding. Compounding moves a present value forward into the future. Discounting moves a future value back into the present.

The previous paragraphs on interest showed that the relationship of a single current amount of money and its future equivalent is:

$$F_n = P(1+i)^n$$

Algebraic manipulation converts this formula into its inverse. Thus, the discounting formula is:

$$PV = F_n*(1/((1.+ i)^n))$$

PV stands for present value.

VARYING THE DISCOUNT RATE

The discount rate and the timing of the cash flows can significantly alter an economic analysis. Lower discount rates favor projects that create the return on their investment late in their project life. Higher discount rates favor projects that create the return on their investment early in their project life. Tables 8-1, 8-2, and 8-3 illustrate the effects of high and low discount rates on cash flows. As a common basis for the comparison, Figure 8-1 shows two cash flows, discounted at ten percent. As Table 8-1 shows, both cash flows have accumulated present values of $500.

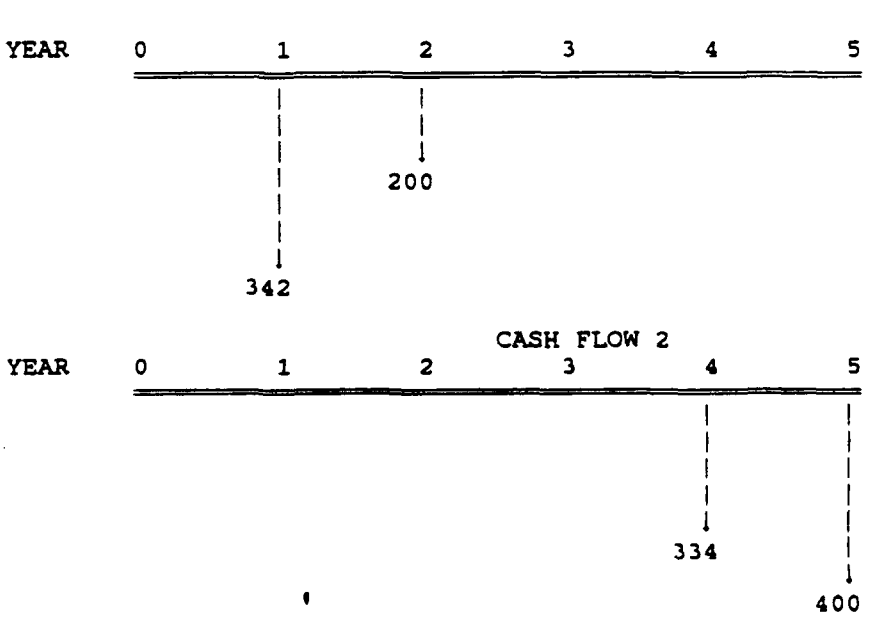


Figure 8-1

TABLE 8-1

CASH FLOW DIAGRAM SHOWING FRONT AND REAR END LOADING
10 PERCENT DISCOUNT RATE

CASH FLOW 1

YEAR	1	2	3	4	5
DISCOUNT FACTOR	0.955	0.868	0.789	0.717	0.652
x CASH FLOW	x 324	x 200	x 0	x 0	x 0
PRESENT VALUE	326	174	0	0	0
CUMULATIVE PV	326	500	500	500	500

CASH FLOW 2

YEAR	1	2	3	4	5
DISCOUNT FACTOR	0.955	0.868	0.789	0.717	0.652
x CASH FLOW	x 0	x 0	x 0	x 334	x 400
PRESENT VALUE	0	0	0	240	261
CUMULATIVE PV	0	0	0	240	500

Note that *CASH FLOW 2* has a significantly greater *absolute* cash flow in order to "pay" for the time value of money. However, using the ten percent discount rate, you conclude that the flows, economically speaking, are equals.

Tables 8-2 and 8-3 evaluate these cash flows, changing only the discount rate.

A one percent discount factor favors investments having heavy, later year cash flows. In this diagram, both cash flows have a cumulative present value of $500 if you evaluate them at ten percent. However, when you evaluate them using a one percent discount rate, you create a difference, on paper, of $155.

A low discount rate gives little attention to the time value of money. Benefits the project achieves in the late years can easily offset the investment costs you pay during the early years of a project. Thus, a low discount rate makes more projects appear feasible, thereby enticing you to undertake more projects with low returns. Applied over the breadth of an organization, you reduce the efficiency of the organization. Applied over the entire nation, choosing poorer investments could lower the rate of national economic growth.

TABLE 8-2

CASH FLOW DIAGRAM SHOWING FRONT AND REAR END LOADING
ONE PERCENT DISCOUNT RATE

CASH FLOW 1

YEAR	1	2	3	4	5
DISCOUNT FACTOR	0.995	0.985	0.975	0.966	0.956
x CASH FLOW	x 324	x 200	x 0	x 0	x 0
PRESENT VALUE	340	197	0	0	0
CUMULATIVE PV	340	537	537	537	537

CASH FLOW 2

YEAR	1	2	3	4	5
DISCOUNT FACTOR	0.995	0.985	0.975	0.966	0.956
x CASH FLOW	x 0	x 0	x 0	x 334	x 400
PRESENT VALUE	0	0	0	323	382
CUMULATIVE PV	0	0	0	323	705

TABLE 8-3

CASH FLOW DIAGRAM SHOWING FRONT AND REAR END LOADING
19 PERCENT DISCOUNT RATE

CASH FLOW 1

YEAR	1	2	3	4	5
DISCOUNT FACTOR	0.920	0.773	0.650	0.546	0.459
x CASH FLOW	x 342	x 200	x 0	x 0	x 0
PRESENT VALUE	315	155	0	0	0
CUMULATIVE PV	315	469	469	469	469

CASH FLOW 2

YEAR	1	2	3	4	5
DISCOUNT FACTOR	0.920	0.773	0.650	0.546	0.459
x CASH FLOW	x 0	x 0	x 0	x 334	x 400
PRESENT VALUE	0	0	0	182	184
CUMULATIVE PV	0	0	0	182	366

A 19 percent discount factor favors investments having heavy, early year cash flows. In this diagram, both cash flows have a cumulative present value of $500 if you evaluate them at ten percent. However, when you evaluate them using a 19 percent discount rate, you create a difference, on paper, of $104.

A high discount rate, 19 percent compared to 1 percent, places a greater emphasis on current costs. Thus, the project's savings in the out years have less impact, offsetting investment costs. This lowers the incentive for investments.

CHAPTER 9

GOVERNMENT DISCOUNT RATES

INTRODUCTION

The government recognizes the effects of money on time. In the DOD, when evaluating investment projects, you must apply discounting whenever the costs or cash benefits of a project would extend over three years or more from the project inception date. The prescribed DOD discount rate is ten percent.

The standard DOD discount rate provides several benefits. First, you do not have to research for an appropriate rate. Second, using the DOD rate provides a common basis for economic analysis. Finally, using the DOD rate stops you from altering it to make one alternative look more favorable than another.

Use the ten percent discount factor to evaluate government projects. Both DOD Instruction 7041.3 and OMB Circular A-94, "Discount Rates to be used in evaluating time-distributed costs and benefits," endorse this rate and consider it to be the most representative overall rate at the present time. This rate is an estimate of the average rate of return on private investment before corporate taxes and after adjusting for inflation. Thus, the ten percent rate is the weighted average opportunity cost of taking money from the private sector.

PRESENT VALUE TABLES

Chapter 8 developed the discount factor $1/(1+i)^n$. You can easily apply this formula to simple examples where cash flows occur in the early years of the project. However, when you evaluate more complex projects involving cash flows throughout the entire economic life, the computational task of applying the formula becomes quite tedious. Table 9-4 is a convenient list of 10% discount factors.

The factors in Table 9-1 are "end-of-year" factors. They assume that the cash flows occur precisely at the ends of years. Generally, costs occur throughout the year. When costs equally occur throughout the year, the midpoint of the year represents the average time of spending. The DOD currently employs factors derived from the standard present value formula to represent an average for the year.

TABLE 9-1

PRESENT VALUE - 10% DISCOUNT FACTOR

YEAR	PRESENT VALUE FORMULA	PRESENT VALUE FACTOR
0	$\frac{1}{(1 + .1)^0}$	1.000
1	$\frac{1}{(1 + .1)^1}$	0.909
2	$\frac{1}{(1 + .1)^2}$	0.826
3	$\frac{1}{(1 + .1)^3}$	0.751
4	$\frac{1}{(1 + .1)^4}$	0.683
	$\frac{1}{}$	

Table 9-2 illustrates the conversion from-end-of-year to average factors. Table A of Appendix C provides a complete list of present value factors for years 1-30.

TABLE 9-2

END OF YEAR VERSUS AVERAGE DISCOUNT FACTORS (10%)

YEAR	END OF YEAR FACTOR	AVERAGE FACTOR FORMULA	AVERAGE FACTOR
0	1.000	$((1/(1+.1)^0)+(1/(1+.1)^0))/2$	1.000
1	0.909	$((1/(1+.1)^0)+(1/(1+.1)^1))/2$	0.955
2	0.826	$((1/(1+.1)^1)+(1/(1+.1)^2))/2$	0.868
3	0.751	$((1/(1+.1)^2)+(1/(1+.1)^3))/2$	0.789
4	0.683	$((1/(1+.1)^3)+(1/(1+.1)^4))/2$	0.717
5	0.621	$((1/(1+.1)^4)+(1/(1+.1)^5))/2$	0.652

The rationale for using average factors instead of end-of-year factors is:

1. After the initial investment cost, most of the annual costs and benefits associated with a project do not occur at a single point in time but rather occur throughout the year. This is typically true of operating costs and salaries. If these costs occur uniformly throughout the year, an mid-year, annual lump sum payment will approximate these costs.

2. You may not know with certainty the exact time of occurrence of costs and benefits in the out years of an economic life. In the absence of more specific information, you have no reason to assume that these costs and benefits will occur only on the anniversaries of acquisition; they might occur at any point in the year. If the cost occur randomly throughout the year with a normal distribution, you could apply average factors to such costs. Errors on the low side should occur about as often as errors on the high side. In the long run, the errors offset.

The following examples demonstrate the use of Table A factors:

Example 9-1

As one alternative in a certain project, your department is considering leasing additional computer space for a four year period. Annual rental would amount to $10,000. What will be the total discounted cost if you choose this alternative?

Solution

Use Table A discount factors to determine the present value:

PV = \$10,000(.954)+\$10,000(.867)+\$10,000(.788)+\$10,000(.717)
= \$9,540 + \$8,670 + \$7,880 + \$7,170

= \$33,260

To simplify the calculations, factor the recurring \$10,000 from each term. This entails finding the sum of the first four Table A factors, then performing a single multiplication. Thus:

PV = \$10,000(0.954 + 0.867 + 0.788 + 0.717).

You may simplify this further using Table B of Appendix C, a list of cumulative sums of Table A factors. Using Table B, the corresponding cumulative discount factor for the above problem is 3.326. Thus, the present value becomes:

PV = \$10,000(3.326) = \$33,260

However, a final simplification is the use of a computer. Table 9-3 is a computer spreadsheet presentation of the cash flows and their present value.

TABLE 9-3

SPREADSHEET PRESENTATION
EXAMPLE 9-1

YEAR	0	1	2	3	4
DISCOUNT FACTOR	1.000	0.955	0.868	0.789	0.717
x COSTS	x 0	x 10,000	x 10,000	x 10,000	x 10,000
PRESENT VALUE	0	9,545	8,677	7,888	7,171
CUMULATIVE PV	0	9,545	18,223	26,111	33,283

While this is the same result obtained earlier using Table A factors, discrepancies occasionally occur between answers you calculate using the Table A method and a computer. Assuming your arithmetic is correct, you may attribute these to rounding errors. A computer can use a mathematical formula, rather than simple addition of Table A factors to compute its factors.

Two general rules for cumulative discount factors are:

Rule 1 - To find the present value of a series of uniform recurring cash flows beginning in year 1 and continuing through year n, multiply the amount of the annual payment by the nth year factor from Table B, Appendix C.

Rule 2 - To find the present value of a series of uniform recurring cash flows beginning in year m and continuing through year n, multiply the amount of the annual payment by the difference between the factors for year n and year m-1 in Table B, Appendix C.

COMMON MISCONCEPTIONS ABOUT THE TEN PERCENT RATE

A number of misconceptions have arisen regarding the ten percent discount factor. Some of the more common ones are:

1. Some people see the ten percent factor as compensation for the rate of inflation. Do not confuse the process of discounting with inflation. While the concepts both recognize the future dollars are not worth as much as today's dollar, the similarity soon ends. Inflation treats the future dollar for anticipated erosion of the purchasing power of today's dollar (a cup of coffee today costs 75 cents, but the same coffee is expected to cost one dollar in the future). Discounting adjusts a given future dollar level to reveal how many dollars today, drawing interest at a given compound rate, would equate the same number of dollars at the given future date, thus the present value of future dollars. The ten percent discount factor more closely associates with the prime rate and long term bond rate.

2. Some argue that you should not consider the time value of money when evaluating Government investment proposals because the Government has no option of "banking" money to earn a return. Congress sets an overall budget. Money the government does not spend on one project it spends on another. In no case would you invest it to earn interest as in the private sector. Recognize that the "return" implied by the ten percent discount rate does not refer to the result of the Government holding money, but rather to the opportunity cost imputed through the transfer of resources from the private to the public sector.

The Federal Government's investment objective should be to maximize the economic well-being of the nation as a whole. This means that the government must maximize the rate of return from invested resources, regardless of whether the investor is private or public. Therefore, in analyzing an investment, the Federal Government must consider the possible return if they left the funds in the private sector. That is the cost of money or the possible return in the private capital market. This is the conceptual basis for considering time value of money or capital costs of government expenditures.

3. One school of thought maintains that you should determine the discount rate to be equal to the rate paid by the Treasury in borrowing money. This concept is built on the premise that if you undertake particular projects using borrowed funds, you must base the minimum rate of return on the rate of those borrowed funds. However, the government does not finance investment solely with borrowed funds. The government raises a majority of revenue through taxation and uses this involuntary transfer of wealth to finance most government investments. This money could finance private investment. Thus, the private sector rate of return is appropriate.

CHAPTER 10

PRESENT VALUE ANALYSIS

INTRODUCTION

You may use a number of techniques to compare alternatives. Each incorporates the discounting principles that Chapter 9 describes. Present value analysis is an appropriate technique to use whenever the benefits and project lives are the same for all alternatives or when you cannot quantify the benefits. Doing a present value analysis is an easy way to compare alternatives. To perform present value analysis, you put all costs and receipts for each alternative in terms of their worth, as of the date you compare them. The alternative having the lowest present value cost is the least cost alternative. You should recommend it.

USING PRESENT VALUE ANALYSIS

In order to use present value analysis as the sole basis for decision making, the following conditions must apply:

1. Benefits for all alternatives must be equal. If benefits are not equal, the least costly alternative may not be the best alternative. The best alternative may be the one that costs the most, yet produces significantly greater benefits. Thus, when benefits are unequal, you should not base your decision solely on the present value analysis. In such a case, you use the Benefit Cost Ratio as Chapter 15 explains.

2. Service lives of the alternatives must be finite. That is, the estimated life of the alternative has a start and stop date. For example, you estimate that Printer A has a life of 6 years. You estimate that Printer B has a life of 12 years.

3. Service lives of alternatives must be equal, or else you must place them on equal terms. You can accomplish this two ways. The first approach is the "common multiple approach". For example, since you would replace Printer A after 6 years, you can compare both Alternatives A and B on the 12 year service life base. Second, you could compare the alternatives using the shorter life and imputing the residual value of the asset with the longer life. Here, you would use a six year life. At the end of the sixth year you would include the residual value of Printer B as a lump sum in the analysis.

Example 10-1

Suppose two machine do the identical work. Machine A has an economic life of six years, costs $10,000 to buy and $4,000 per year to operate. Machine B has an economic life of 3 years, costs $8,000 to buy and $5,000 per year to operate. Neither machine has salvage value at the end of its economic life. Using present value analysis, which machine should you buy?

Solution

1. Using a six year period of comparison:

   a. The cash flow diagrams are:

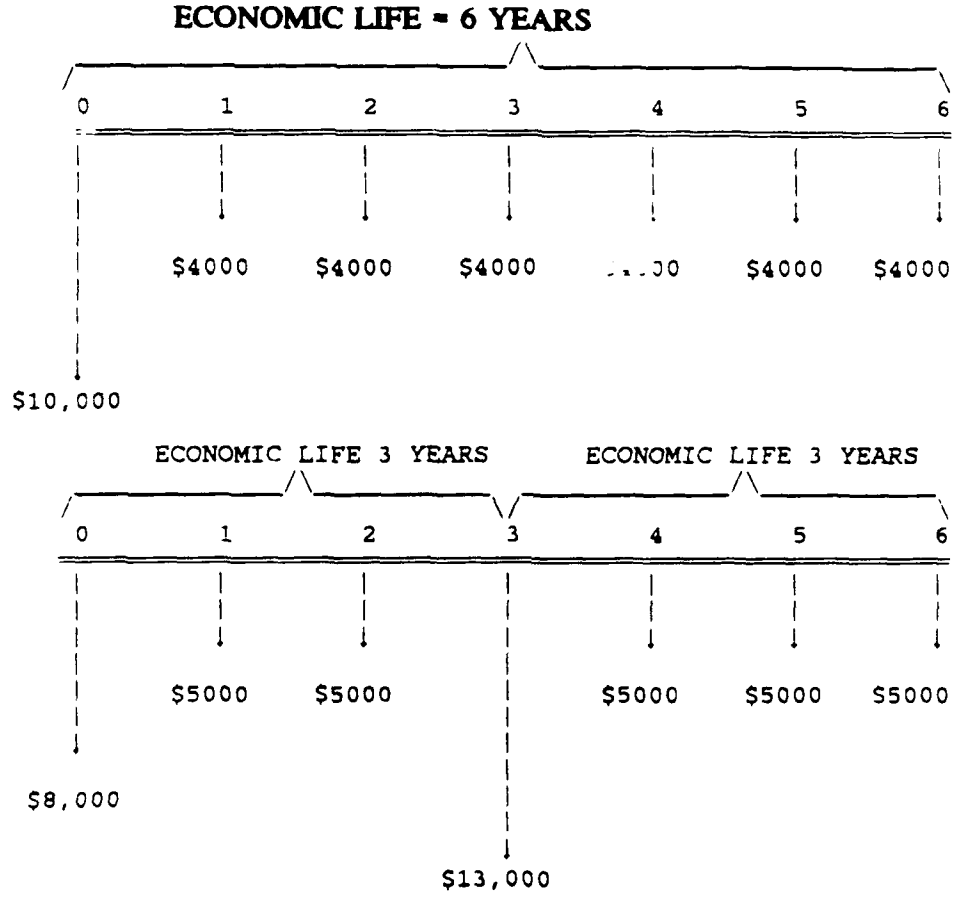


Figure 10-1

   b. Table 10-1 is a present value analysis spreadsheet for this solution.

TABLE 10-1

PRESENT VALUE ANALYSIS
EXAMPLE 10-1

MACHINE A
ECONOMIC LIFE SIX YEARS

YEAR	0	1	2	3	4	5	6
DISC FACTOR	1.000	0.955	0.868	0.789	0.717	0.652	0.593
x CASH FLOW	x $10,000	x $4,000	x $4,000	x $4,000	x $4,000	x $4,000	x $4,000
PV CASH FLOWS	$10,000	$3,818	$3,471	$3,156	$2,869	$2,608	$2,371
ACCUMULATED PV	$10,000	$13,818	$17,289	$20,445	$23,313	$25,921	$28,292
PV MACHINE A							$28,292

MACHINE B
ECONOMIC LIFE 3 YEARS

MACHINE B
ECONOMIC LIFE 3 YEARS

YEAR	0	1	2	3	4	5	6
DISC FACTOR	1.000	0.955	0.868	0.789	0.717	0.652	0.593
x CASH FLOWS	x $8,000	x $5,000	x $5,000	x $13,000	x $5,000	x $5,000	x $5,000
PV CASH FLOWS	$8,000	$4,773	$4,339	$10,225	$3,586	$3,260	$2,963
ACCUMULATED PV	$8,000	$12,773	$17,112	$27,367	$30,953	$34,213	$37,176
PV MACHINE B							$37,176

c. The present value costs are:

$$PVA = \$10{,}000 + \$4{,}000(4.573) = \underline{\$28{,}292}$$

$$PV_B = \$8{,}000 + \$5{,}000(4.573) + \$8{,}000\ (.789) = \underline{\$37{,}176}$$

2. Using a three-year period of comparison:

a. The cash flow diagrams are:

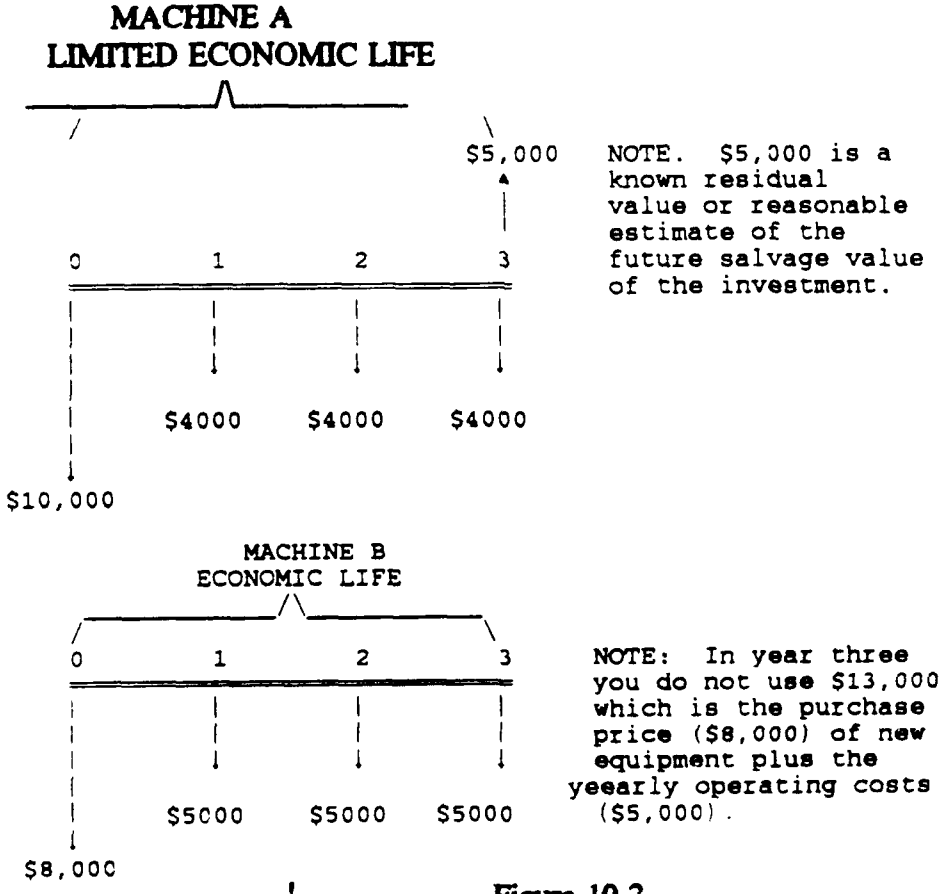


Figure 10-2

b. Table 10-2 is a spread sheet of the present value analysis using a three year period of comparison.

TABLE 10-2

PRESENT VALUE ANALYSIS
3 YEAR ECONOMIC LIFE LIMIT

MACHINE A
LIMITED 3 YEAR ECONOMIC LIFE

YEAR	0	1	2	3
CASH FLOW x DISC FACTOR	$10,000 x 1.000	$4,000 x 0.955	$4,000 x 0.868	($1,000) x 0.789
PRESENT VALUE CASH FLOWS	$10,000	$3,818	$3,471	($789)
ACCUMULATED PRESENT VALUE	$10,000	$13,818	$17,289	$16,500
TOTAL PRESENT VALUE MACHINE A				$16,500

MACHINE B
3 YEAR ECONOMIC LIFE

YEAR	0	1	2	3
CASH FLOW x DISC FACTOR	$8,000 x 1.000	$5,000 x 0.955	$5,000 x 0.868	$5,000 x 0.789
PRESENT VALUE CASH FLOWS	$8,000	$4,773	$4,339	$3,944
ACCUMULATED PRESENT VALUE	$8,000	$12,773	$17,112	$21,056
TOTAL PRESENT VALUE MACHINE B				$21,056

c. The present values of Alternatives A and B for a three year period are:

$$PV_A = \$10,000 + \$4,000(2.609) - \$5,000(.789) = \$16,491$$

$$PV_B = \$8,000 + \$5,000(2.609) = \$21,045$$

The $9 difference is rounding error.

PRESENTING A PRESENT VALUE ANALYSIS

There is no set format for presenting the results of the present value analysis. You are free to design a format which will meet your needs for displaying the data. However, you must organize the information to easily identify the discounted costs for each year of the project life.

Perform the economic analyses of alternative methods of acquisition with care and precision. Frequently, the same vendor will not be low on both lease and purchase plans. The following example describe four acquisition methods:

CHAPTER 11

UNIFORM ANNUAL COSTS

INTRODUCTION

So far, this book limited the comparisons of investment proposals to the use of the present value technique. This involves putting all costs and receipts for each alternative in terms of their worth as of the date you make a comparison. The present value technique best fits alternatives having equal economic lives. However, frequently, the economic lives differ from alternative to alternative. The Uniform Annual Cost (UAC) method puts all the alternatives on a common basis of time in order to make a valid comparison.

UNIFORM ANNUAL COST

The UAC technique is a cost oriented approach you use to evaluate alternatives with unequal economic lives. The technique involves putting all life cycle costs and receipts for each alternative in terms of an average annual expenditure. The alternative with the lowest UAC is the most economical choice.

When using the UAC method to evaluate alternatives, apply the following assumptions:

1. The cash flow diagrams represent alternatives meeting the same requirements specification.

2. You see no end to the requirement and technological considerations play no significant role. Thus, the physical lives constrain the economic lives of Alternatives A and B.

3. The only costs associated with each alternative are the uniform recurring costs.

4. The two alternatives provide an equivalent level of benefits per year. Thus, even if you cannot quantify the benefits, an alternative with a longer economic life will produce more benefits over the course of its life.

5. The annual cost of one alternative exceeds that of the other alternative.

6. You may repeat each alternative indefinitely, with the same cash flow pattern.

To understand the rationale behind this technique, consider the cash flow diagrams in Figure 11-1.

CASH FLOW DIAGRAM - UNEQUAL ECONOMIC LIVES

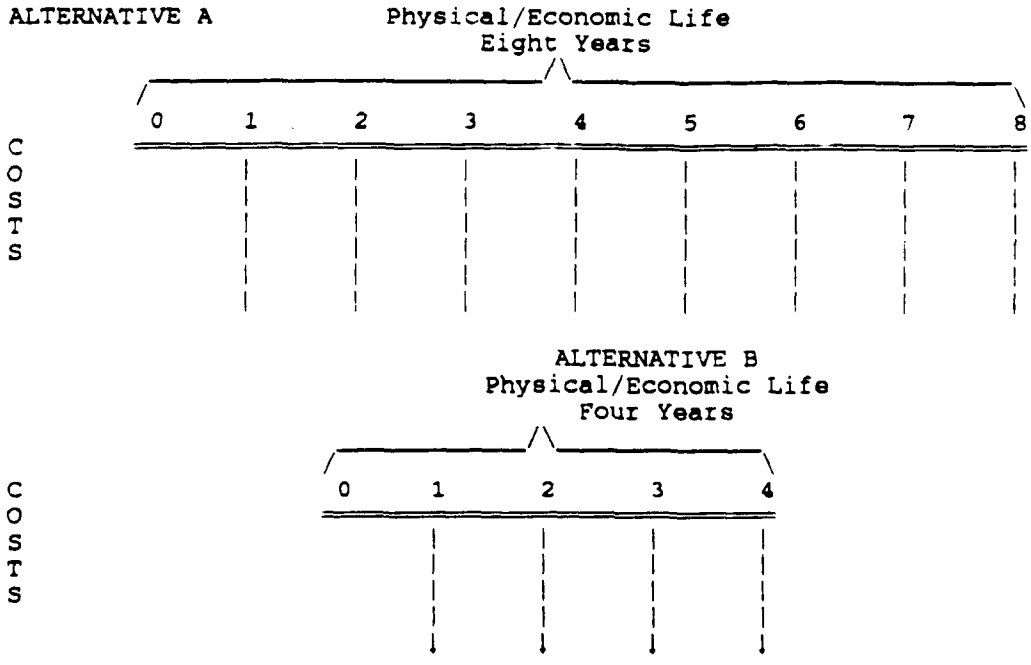


Figure 11-1

Which alternative should you select? While Alternative A costs more per year, Alternative A also provides benefits over a longer period of time. Remember, assumption two states that the requirement is open-ended. However, applying assumption six allows you to use multiples of Alternative B. This provides the new cash flow diagram in figure 11-2.

CASH FLOW DIAGRAM - UNEQUAL ECONOMIC LIVES

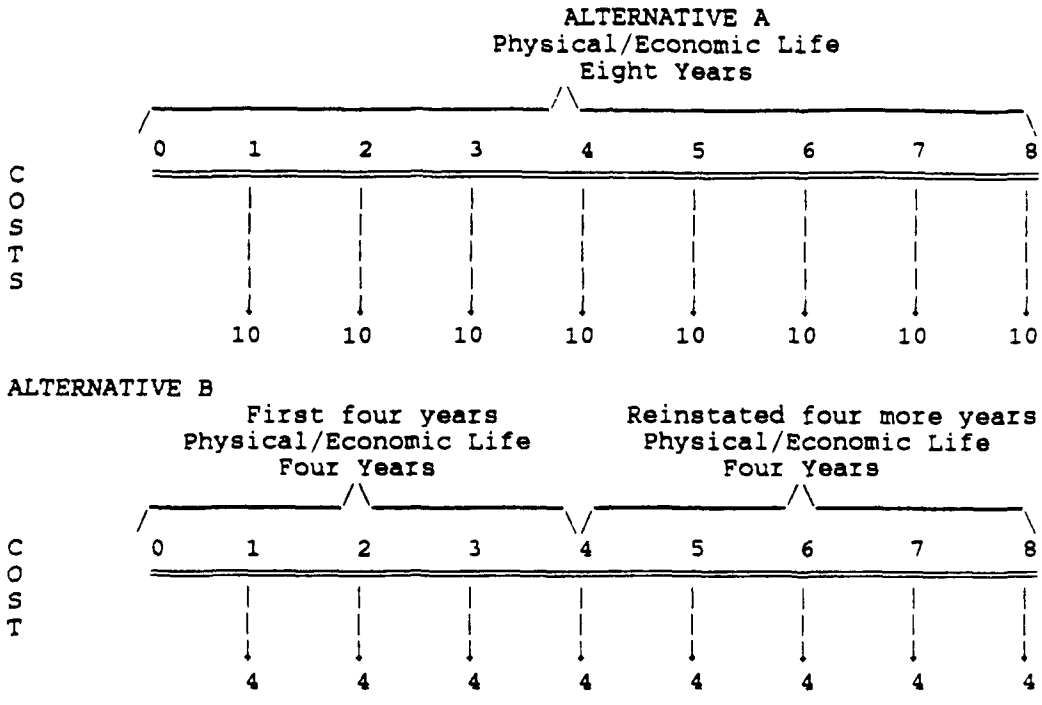


Figure 11-2

This strategy extends both alternatives to a common point in time. Noting assumption four, the alternatives yield comparable benefits per year, the extended alternatives provide equivalent levels of total benefits over the common 8-year period. From Figure 11-2, obviously Alternative B costs less. It requires a smaller expenditure in each of the 8 years. On this basis, you would recommend Alternative B.

In reality, you could scarcely expect cash-flow patterns to be so simplistic. More likely, each alternative might have substantial but varying investment costs, unequal yearly cash flows, and perhaps, residual values in scrap.

A general unequal economic life situation might resemble that of figure 11-3. Here, the better economic choice is not obvious even if you know the costs and economic lives.

The Uniform Annual Cost technique converts each alternative into an equivalent hypothetical alternative having uniform recurring costs such as those in Figure 11-1. The conversion is such that the total net present value costs of the alternative and its hypothetical equivalent are the same. Then, compare the hypothetical alternatives and identify the one with the least, net present value costs. Its corresponding actual alternative is the economic choice for the project.

CASH FLOW DIAGRAMS
TYPICAL UNEQUAL ECONOMIC LIFE SITUATION

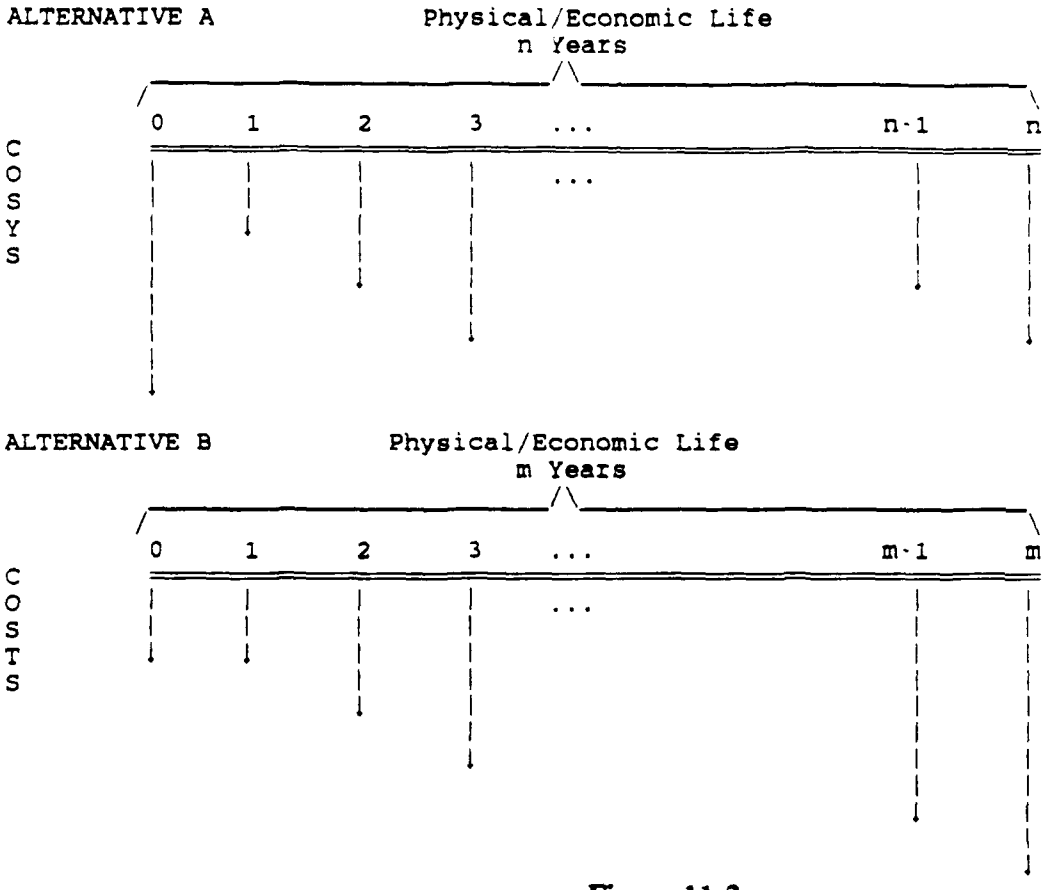


Figure 11-3

CALCULATION OF UAC

The analytical mechanism for calculating the UAC for an actual alternative is:

First, determine the present value cost of the alternative. That is, find the sum of each year's discounted costs using a ten percent discount rate.

Second, divide the PV by the sum of the discount factors for the economic life of the alternative. Table C-1 of Appendix C provides cumulative discount factors. Thus, the formula for determining the Uniform Annual Cost becomes:

$$UAC = \frac{PV}{b_n}$$

where b_n represents the nth year Table C-1 factor.

The UAC represents the amount of money you would need in equal yearly installments to pay for the project.

Note, the UAC is not the same as taking a straight average. For example, a building with a 25-year life and an acquisition cost of $100 million has an average annual acquisition cost of $4 million. Using the technique of UAC, the annual cost is approximately $10 million.

Simple Average	UAC
$\frac{\$100M}{25} = \$4M$	$\frac{PV}{b_n} = \frac{\$100M}{9.524} = \$10M$

Using a simple average to determine average annual cost for economic analysis purposes is inappropriate because it fails to acknowledge the time value of money. On the other hand, the UAC incorporates this concept in its formula. The significance of the $10 million uniform annual cost above is this: Were you to spend $10 million each year for 25 years, the total net present value of the payments would be $100 million, the same as the actual net PV cost of the alternative.

The financing of a new car provides a typical example of the use of the UAC concept. When purchasing a new car on time payments, the finance company will use the UAC concept to arrive at the amount and number of payments necessary to reduce the balance to zero. Since car payments usually are monthly, they base the payments on an equivalent monthly cost instead of equivalent annual cost. The payments will be higher than the simple arithmetic average due to interest charges. Thus, UAC is a type of average cost that includes interest costs.

Example 11-1

Suppose you will purchase new computers for your office. You are considering two equally effective alternatives and have collected the following information:

	Alternative A	Alternative B
Initial Cost	$325,000	$300,000
Operating Costs		
Year: 1	35,000	25,000
2	35,000	25,000
3	35,000	25,000
4	45,000	45,000
5	60,000	30,000
6	35,000	
7	35,000	
Service Life	7 years	5 years

Which is the more economical equipment to own and operate?

Solution

First, compute the PV cost for the alternatives. Your calculations are:

PV_A = \$325+35(2.609)+\$45(.717)+\$60(.652)+\$35(5.108-3.977)= \$527

PV_B = \$300+\$25(2.609)+\$45(.717)+\$30(.652)= \$417

You then divide each PV by the cumulative present value factor corresponding to that alternative's economic life. The uniform annual cost computations for the two alternatives are:

Alternative A: $UAC_A = \frac{PV}{b_7} = \frac{PV_A}{5.108} = \frac{\$527}{5.108} = \$103$

Alternative B: $UAC_B = \frac{PV_B}{b_5} = \frac{\$417}{3.977} = \$105$

Since Alternative A has the lower uniform annual costs, recommend it.

UAC AND LEAD TIME

Because the UAC is a comparison of total cost per production year, when using the UAC technique, you should spread the cash flows over the actual economic life only. Treat costs you incur during lead time as investment costs. Consider the following:

A generalization of the approach in this example is: If an alterative has a project life of n years, of which the first m years are lead time, therefore not part of the economic life, its uniform annual cost is given by:

$$UAC = \frac{PV}{b_n - b_m}$$

In this example, Alternative A is economically preferable because it has the lower uniform annual cost.

However, had you mistakenly divided $904 by 7.980 (the 15-year cumulative present value factor), the UAC computation for Alternative B would have been $113. Since this is less than the UAC obtained for Alternative A, you would erroneously conclude that Alternative B is preferable.

SUMMARY

Uniform Annual Cost is an economic analysis technique comparing two or more alternatives having different lives. The technique converts a stream of expenditures over a number of years to a constant amount for each year in the time frame. Calculation of the UAC involves dividing the present value of the alternative by the cumulative discount factor associated with its economic life, thereby taking into account the time value of money. Thus, the analysis does not reflect actual cash outlays. Rather, you use the analysis for comparison purposes as part of the decision-making process.

CHAPTER 12

SAVINGS/INVESTMENT RATIO

INTRODUCTION

A Savings/Investment Ratio (SIR) is the relationship between future cost savings and the investment necessary to those obtain savings. A SIR of 1 indicates that the PV of the savings is equal to the PV of the investment. For an investment to be economically sound, the SIR must be greater than 1.

Notice that this discussion does not mention benefits. The SIR is a characteristic of costs only. You use it to analyze individual investments or to rank competing investment projects.

COMPUTATION OF SIR

To understand the concept of SIR, consider Figure 12-1. Cash flow Diagram A depicts the status quo, Diagram B a proposed alternative. Both extend over an economic life of n years.

CASH FLOW DIAGRAMS - SIR EXAMPLE

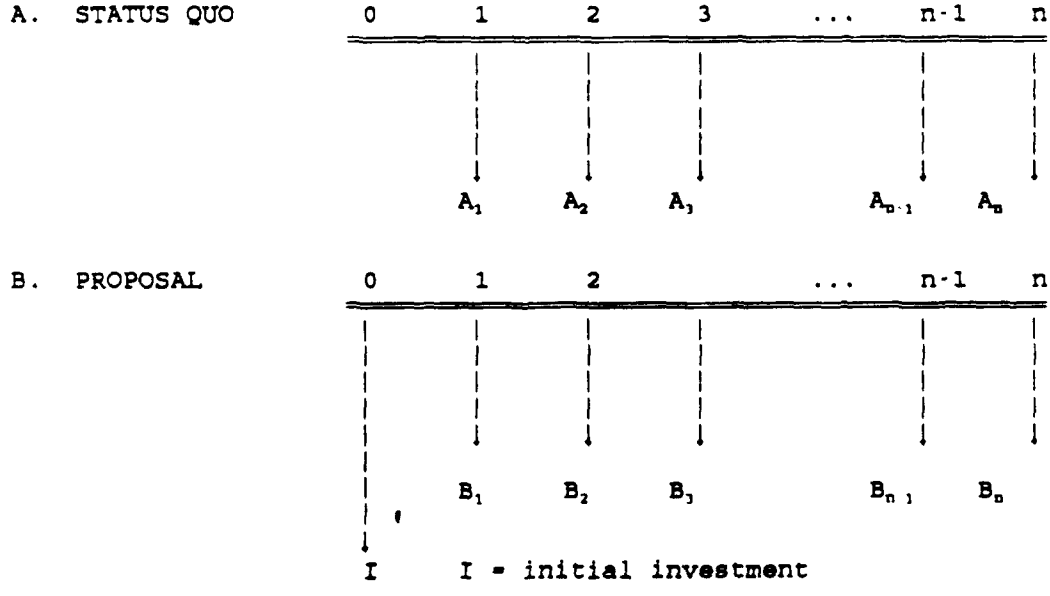


Figure 12-1

When computing an SIR, your interest is not in total operating costs. Rather, you're interested in the difference between life cycle operating costs for two alternatives. The difference is the effect the investment has on the operation. Thus, the crucial question in Figure 12-1 is: Do the recurring savings of B (relative to A) warrant the investment I? Savings is the amount of annual expenditure you were incurring but which a proposed alternative reduces.

In Figure 12-1, the total PV savings (PV_S) of Alternative B (relative to A) are:

$$PV_S = PV(A_1 - B_1) + PV(A_2 - B_2) + \ldots + PV(A_n - B_n)$$

The savings/investment ratio is:

$$SIR = \frac{PV_S}{I}$$

You should not initiate Alternative B unless its SIR exceeds unity. That is, unless its future discounted savings more than offset its discounted investment cost.

REFINEMENT OF SIR

The SIR in figure 12-1 captures the essence of the savings/investment ratio idea. To further refine the SIR, closely examine the nature and timing of the cost elements involved. For example, if the initial investment I associated with Alternative B extends beyond one year, put the total present value of I into the SIR, yielding:

$$SIR = \frac{PV_S}{PV_I}$$

If Alternative B also includes a terminal value T, use the present value of the investment I less the terminal value T.

$$SIR = \frac{PV_S}{PV_I - PV_T}$$

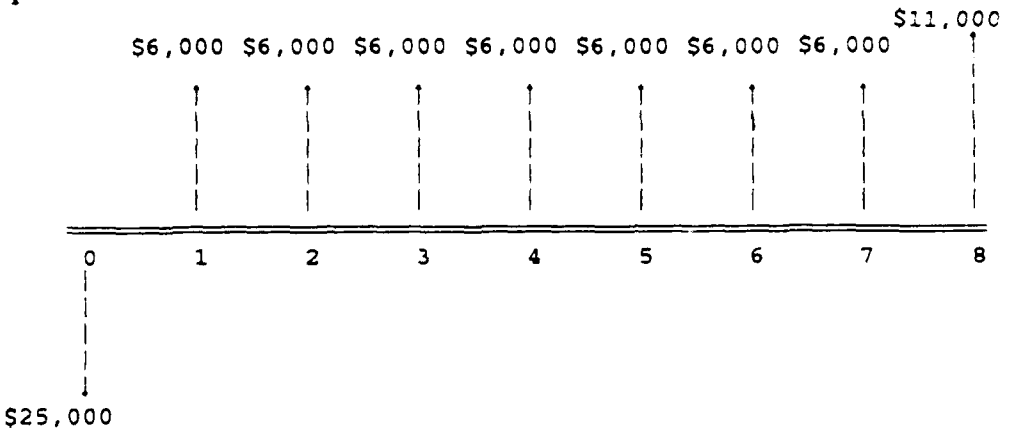
The presence of other cost elements, such as the value of assets replaced or a refurbishment cost to sustain the status quo would require that you further refine the SIR formula.

Example 12-1

Suppose you consider purchasing a numerically controlled cutting machine. The initial investment is $25,000. You anticipate that this machine will reduce operating costs $6,000 per year during its 8 years of operation. Salvage value after 8 years is $5,000. Is this an economical investment?

Solution

A single cash flow diagram depicting the difference between the proposed alternative and the status quo is:



To calculate the SIR, you determine the ratio of the present value of the savings to the present value of the investment less the present value of the terminal value:

$$SIR = \frac{PV_s}{PV_I - PV_T}$$

$$= \frac{\$6{,}000(5.597)}{\$25{,}000 - \$5{,}000(.489)}$$

$$= \underline{1.49}$$

Since the SIR is greater than 1.0, the investment is economically sound. That is, the present value of the cutting machine savings are greater than the present value of its cost. _____

COMPARING COMPETING INVESTMENT PROJECTS

The SIR reflects the savings that result from each dollar you invest. The greater the SIR, the more profitable the investment. for example, an investment with a SIR of 1.25 is more profitable than an investment with a SIR of 1.10. It yields 15 cents more savings for each dollar you invest.

The Government does not base decisions to fund projects solely on economics. Benefits, which the SIR does not consider, also play an important role. However, if you disregard benefits and assume that a number of investment programs are equally worthwhile, then the SIR technique is a valid decision tool for setting priorities among investment projects.

USING SIRS IN ECONOMIC ANALYSES

You can use the SIR technique to set priorities among various unrelated projects. Generally, with limited funds, you initiate projects with the highest SIRs. However, in an economic analysis, you focus on a single project and the alternative ways of accomplishing it. While you compare and rank a number of alternatives against each other, you select only one, the least costly alternative.

The SIR relates a proposed alternative to its status quo. When a project has more than one alternative, the SIR technique will determine which one produces the most savings per dollar invested. As it turns out, the alternative with the greatest SIR also has the greatest present value. Example 12-3 demonstrates how you can use the SIR to compare alternatives.

CHAPTER 13

DISCOUNTED PAYBACK ANALYSIS

INTRODUCTION

Probably, the most widely understood method for comparing alternative investments (or for evaluating a single investment) is "payback" analysis. Payback is the period of time a project's accumulated savings require to offset its investment costs. Thus, a project costing $100 yielding annual savings of $25 would have a four-year payback period. You use Discounted Payback Analysis when the speed of investment recovery is critical.

Note that the duration of a project's life does not effect the economic connotation of payback. For example, a 4.5 year payback is the same whether the economic life is 10 or 25 years.

DISCOUNTED PAYBACK ANALYSIS

The Navy views payback analysis differently. The example in the introduction has two major shortcomings.

First, the four year payback represents a payback without discounting. By failing to recognize the timing of cash flows within a project payoff period, this payback ignores an important element, the time value of money. For example, a project costing $350,000 that will return $50,000 per year for 10 years appears to be a good investment. The return will be $500,000. The project will amortize itself in seven years. However, applying a ten percent discount factor over the full 10 years yields present value savings of only $322,350. Thus, such a return would not adequately cover investment costs.

Second, the conventional notion of payback analysis fails to address cash flows beyond a period necessary to recover initial investment costs. If significant one-time costs occur after the estimated point of payback, such as for a major repair or overhaul , you overstate the attractiveness of the project.

By incorporating a time value element and including all future cash flows, you can modify the payback period concept to determine the discounted payback period. Thus, a project achieves payback when accumulated present value savings are sufficient to offset, or amortize the total present value cost of a proposed alternative. The payback period is simply the time between the point of initial investment and the point at which payback occurs. As noted in Chapter 2, since savings are a necessary factor for computing payback, you use this technique when you can compare your alternative to the status quo.

This differs from the private sector that achieves payback when profits offset investment. Thus, they can compute payback even when they don't know the status quo. However, since the Government is not in the business to make a profit, this limits using the payback technique if you don't know the status quo.

Example 13-1

Suppose preliminary studies indicate that a new printer will save your office $1,500 annually. The cost of the printer is $5,000 and during the fifth year it will require significant maintenance costing $3,000. The printer has an economic life of eight years and a terminal value of $500. Determine the discounted payback period for the equipment.

Solution

The present value less terminal value of the equipment is:

$PV_I - PV_T = \$5000 + .652\ (\$3000) - 489\ (\$500) = \underline{\$6712}$

$PV_S = \$1500\ (5.60) = \underline{\$8400}$

Where:

PV_I is the present value of your investment.
PV_T is the present value of its terminal value.
PV_S is the present value of your savings.

Since total life-cycle savings of $8,400 are greater than the investment cost, the proposed alternative is economical and you should implement it. The project will recoup total investment costs around year 6 when $PV_S = PV_I - PV_T$.

To find the exact point of payback, use interpolation. First subtract year 5 Cumulative PV_S from the PV_I ($6,712 -($1500 * 3.977) = $745). This is the discounted dollar value of savings which attribute to payback . Next, divide this amount by the total PV(S) for year 5 to find the proportion of that year during which the savings payback the investment ($745/$888 =.839). Thus, the "discounted payback" is 5.8 years.

NOTE: The cumulative discount factor computed above corresponds to the period of time during which the alternative is accruing savings (i.e. its economic life). When an alternative has lead time, you must add the lead time to adjust the cumulative factor.

ADVANTAGES OF PAYBACK

The discounted payback period lets you know exactly how long it will take to recoup costs. Alternatives with short payback periods cut the risks that unforeseen events will stop them from recouping their costs. For example, changing technology could suddenly render your system obsolete and insupportable long before payback occurs.

DISADVANTAGES OF PAYBACK

Payback has several disadvantages. First, payback favors alternatives having low investment costs and high earnings. Next, payback provides no means of comparing lease-versus-buy alternatives, since the lease may require no initial investment cost. This of course would yield a zero payback period regardless of the length of the leasing contract. Finally, payback will not necessarily identify the least costly alternative; it merely identifies the point in time when total investment costs will be recouped. Payback fails to consider those additional savings which occur beyond the payback period.

CHAPTER 14

BREAK-EVEN ANALYSIS

INTRODUCTION

Break-even analysis is an important analytical technique used to study the relationship between alternative cost patterns. In break-even analysis, you focuses on finding the value of a variable (the "break-even point") at which you're indifferent between two possible courses of action. At the break-even point, the economic desirability of the two alternatives is equal. To either side of the break-even point, one alternative or the other has the economic advantage.

BREAK-EVEN CHART

Figure 14-1, a basic break-even chart, depicts the nature of break-even analysis. The horizontal axis measures time in yearly intervals. However, you could use any other convenient and meaningful measurement, such as the number of units produced or hours of machine operation. The vertical axis measures dollars. The curves measure the discounted life cycle cost patterns for each of the alternatives.

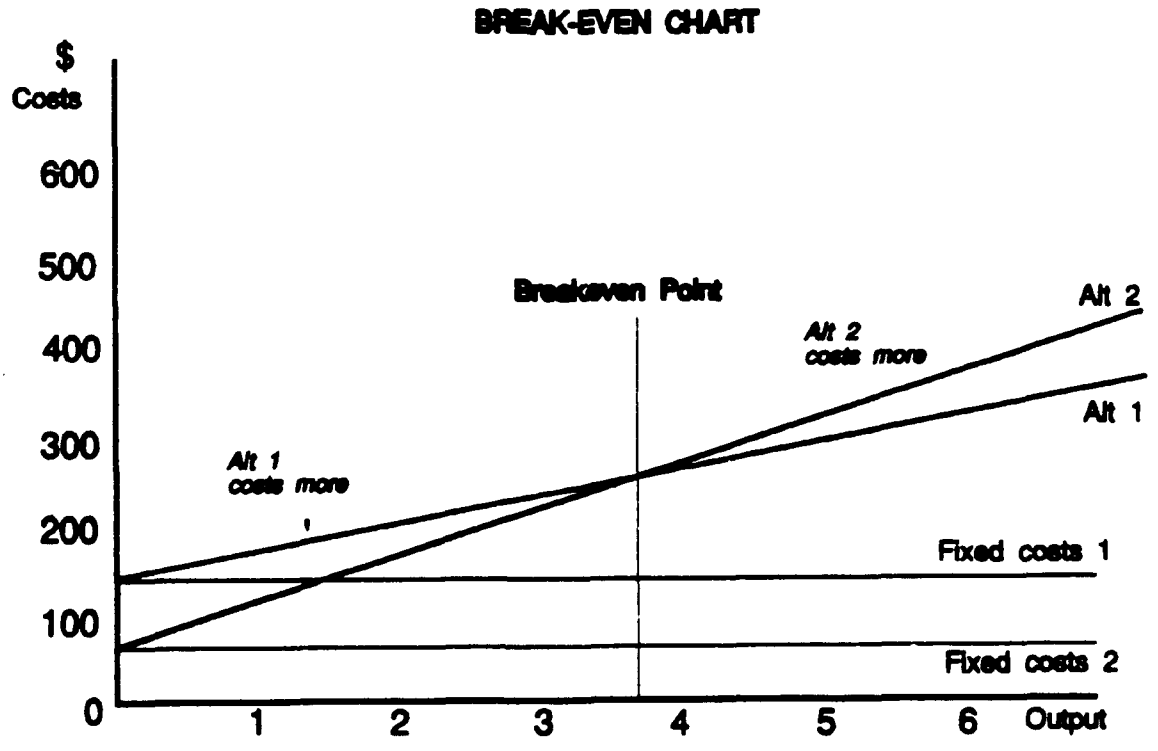


Figure 14-1

The intersection of the two cost curves determines the break-even point. In this case, it occurs during year four. To the left of the point the cumulative cost for Alternative 2 is less than for Alternative 1. At the break-even point the costs are equal. To the right, the cumulative cost of Alternative 1 is less than Alternative 2.

Break-even charts are useful in economic analyses because they provide you with the capability to visually compare alternatives at any point in time or output. They are convenient, effective, readily accepted and easily understood.

BREAK-EVEN ANALYSIS AND VARIABLE OPERATING COSTS

Break-even analysis is useful for analyzing the financial characteristics of an alternative upon some future variable such as the number of units produced, the number of hours of machine operation, or the quantity of packages handled. The analysis focuses on how total costs vary with output as operations become automated or mechanized, substituting fixed for variable costs.

Example 14-1

Suppose you're selecting between two types of printers. Each has a certain cost of setting up the equipment for production. Additionally, each has a charge for every page it produces. Given the following cost data, determine the job size that represents the break-even point for the alternatives:

	Printer A	Printer B
Set up costs	$2.00	$3.50
Unit cost per page	$.015	$.010

Solution

Figure 14-2 depicts the break-even analysis. The vertical axis is dollars per job while the horizontal axis is pages per job. The curves represent the costs for each machine. The cost for Printer A is below the cost for Printer B when the jobs have fewer than three hundred pages. When a job requires more than three hundred pages, Printer B is cheaper. Of course, if the job requires exactly three hundred pages then the two machines have the same costs.

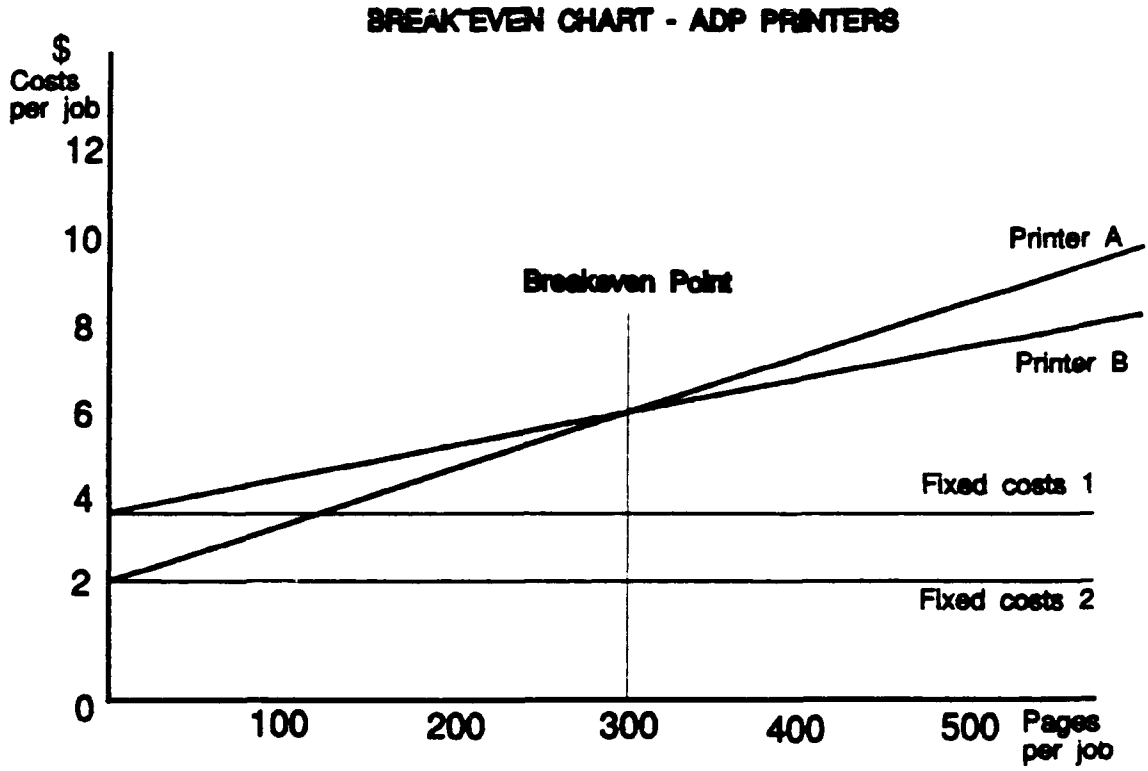


Figure 14-2

ALGEBRAIC BREAK-EVEN ANALYSIS

Although break-even charts are a useful to illustrate cost relationships, algebraic techniques typically are more efficient for analyzing decision problems. The algebraic technique for solving a break-even problem consists of setting the cost equations for each alternative equal and solving the unknown.

The general cost equation is: TC = FC + VC(x) where:

TC = Total cost FC = Fixed cost
VC = Variable cost x = Unknown break-even point

The two equations for Example 14-1 become:

TC (Printer A) = \$2.00 + \$.015x
TC (Printer B) = \$3.50 + \$.010x

Setting them equal and solving for x gives:

$$\$2.00 + \$.015x = \$3.50 + \$.010x$$
$$\$.005x = \$1.50$$
$$x = \underline{300}$$

Thus, the break-even point is three hundred pages.

INCORPORATING PRESENT VALUE OF CASH FLOWS

Given that you compare the alternatives during the same period, or the cash flows are equal throughout all periods, you do not need to include present value analysis. On the other hand, if you have varying cash flows, or an initial investment, you must convert your cash flows into their present values and then complete your break-even analysis.

CHAPTER 15

BENEFIT COST RATIOS

INTRODUCTION

So far, you have considered techniques to compare only the cost of alternatives. These techniques are useful if benefits associated with all alternatives are comparable. However, you will discover many instances when the assumption of equivalent benefits is a poor one. Therefore, you must devise some method to compare both the costs and the benefits of alternatives. The Benefit Cost Ratio (BCR) is an accepted and recommended method.

BENEFIT COST RATIO

One of the first things to consider when evaluating a possible investment is whether it will yield benefits commensurate with the costs. To determine the economic desirability of an investment you divide the benefits by the costs, calculating the BCR. This gives you a single number or value for the investment. This value represents the amount of benefits obtained per unit of cost.

You compute a separate BCR for each alternative. The alternative with the highest BCR is the *most cost effective*. That is, it returns the most benefits for each dollar spent. The method of computing the BCR will vary from analysis to analysis depending upon the number of benefits involved and whether the benefits are quantifiable. But, in all cases, since you spread costs over a designated period of time, you must account for the time value of money in the calculation.

BCR AND QUANTIFIABLE BENEFITS

Many projects have a stated goal defined in terms of required output, such as, to reduce errors, to decrease response time, or to process an increased workload. The goal is not always quantified, but it often is susceptible to quantification and thus provides a potential measure of benefits associated with the project.

When you can quantify output, the appropriate formula for the BCR is:

$$\text{BCR} = \frac{\text{Quantifiable Output Measure}}{\text{Uniform Annual Cost}}$$

In this expression, you calculate the Uniform Annual Costs as Chapter 11 described. You use the UAC in the calculation because it accounts for both the time value of money and the fact that alternatives often have different economic lives. The quantifiable output measure is a statement of expected output over some designated period of time for the alternative under investigation. You should not attach significance to the fact that a computed BCR may be less than unity. This is due

entirely to the dimensional quality of the BCR and the arbitrarily chosen baseline, such as, cards punched per minute versus cards punched per hour. The only valid comparison is between the two ratio measures. Their relationship to unity has no significance. Do not confuse this with the savings investment ratio where the effect of unity is crucial.

Some examples of quantifiable output measures are:

- o Number of pages printed per hour
- o Number of reports generated per week
- o Number of work orders processed per month
- o Number of transactions recorded per minute
- o Decreased error rate per job

This list is not exhaustive, but it should provide you with a good perception of what a measure is, and should assist you in formulating specific measures tailored to your particular analytical problem. Note that you already account for savings in the cost analysis and, therefore, cannot count them again as an output measure.

When using this technique, you should use the most significant output factor to compute the BCR. When you have several significant factors, you may compute a BCR for each.

Example 15-1

Suppose you periodically review government contractors to assure that they comply with equal opportunity standards. Currently, you use a manual process to collect, analyze and maintain this data. You should review each contractor annually. However, because the manual process is slow and tedious, you review only 23% of the workload, 39,000 reviews per year. An automated information system could double the number of reviews performed by reducing much of the manual effort dedicated to scheduling reviews and generating follow-up reports. Costs for the two alternatives are:

	Manual	Automated	
One-time (year 1)		$2,175,000	Recurring (years 2-9)
	$1,650,000	$2,050,000	

Using the annual number of reviews as a measure of benefits, determine the BCR for each alternative.

Solution

You compute a BCR for the manual and automated systems using the following formula:

$$BCR = \frac{\text{Quantifiable Output Measure}}{\text{Uniform Annual Cost}}$$

The quantifiable output measures for the automated and manual systems are 78,000 and 39,000, respectively. Using the uniform annual cost formula developed in Chapter 11, you compute the UAC to be:

$$UAC = \frac{PV}{b_n - b_m}$$

$$\text{UAC (Automated)} = \frac{\$2,175,000(.954) + \$2,050,000(6.042-.954)}{6.042 - .954}$$

$$= \frac{\$2,074,950 + \$10,430,400}{5.088}$$

$$= \$2,457,812$$

$$\text{UAC (Manual)} = \frac{\$1,650,000(6.042 - .954)}{6.042 - .954}$$

$$= \frac{\$8,395,200}{5.088}$$

$$= \$1,650,000$$

By substituting the quantifiable output measures and the UAC into the BCR formula you get:

$$\text{BCR (Automated)} = \frac{78,000}{\$2,457,812} = .032$$

$$\text{BCR (Manual)} = \frac{39,000}{\$1,650,000} = .024$$

The proposed automated system has a higher BCR than the current manual system. Therefore. it is the more cost-effective alternative.

BCR AND NON-QUANTIFIABLE BENEFITS

Even when you can't quantify benefits, you can still use the BCR technique by calculating an Aggregate Benefit Value (ABV). To do so, you identify factors within the alternatives that are important to your decision. Next, you assign weights to the factors to establish their relative importance to one another. Then, based on the decision factors, you rank each alternative on a scale of 0 to 10, where 0 means "of no value" and 10 represents an "attainable ideal". Lastly, you multiply the ranking of each factor by the factor weight and sum the results. This is the ABV. You use this in lieu of a benefit.

Table 15-1 illustrates one possible approach for developing an aggregate benefit value.

TABLE 15-1
BENEFIT RANKINGS - - AUTOMATED

Decision Factor	Factor Weight	Ranking	Product
Data availability	3	9	27
Data timeliness	2	8	16
Data accuracy	2	6	12
Decision making	3	9	27
Summation			82
UAC			2.46
BCR			33.36

BENEFIT RANKINGS -- MANUAL

Decision Factor	Factor Weight	Ranking	Product
Data availability	3	7	21
Data timeliness	2	10	20
Data accuracy	2	7	14
Decision making	3	8	24
Summation			79
UAC			1.65
BCR			47.88

CHAPTER 16

UNCERTAINTY

INTRODUCTION

Depending upon the amount of information or the number of facts available, while performing an economic analysis, you will find yourself in one of two environments: "certainty" or "uncertainty". Under certainty, you understand all facts, actions and results. Under uncertainty, you do not know all the facts. You must make various assumptions in order to create a workable environment. When uncertainties exist in an analysis, you must carefully examine each to determine its effect and influence on the ultimate analysis recommendation.

CERTAINTY

The ideal environment for decision making is one where you know all things: You have no doubt, no uncertainty. You know exactly what will happen, when it will happen, and all other related aspects. You need no formulation of assumptions, step two in the economic analysis process, because you know everything. Obviously, you seldom, if ever, encounter this type of environment.

UNCERTAINTY

The estimates of costs and benefits considered so far are average, predicted, or expected outcomes. But, you know that for all sorts of reasons, these amounts may be off the mark. The actual costs of development or production never coincides exactly with advance estimates. This is not because you are lazy or careless in your estimation. Rather, the inherent uncertainty surrounding the current and future environment causes the difference. The most common types of uncertainty are:

Uncertainty about planning and cost factors. Every model uses as inputs certain relations between its elements. These are known as planning factors. For example, planning factors are the time it takes to perform a certain function, the number of people required to accomplish a given workload, the amount of CPU time required to run a particular program. Planning factors are the main ingredient in estimating costs. Because you cannot always predict this information with complete accuracy, uncertainty will exist in the analysis.

Requirements Uncertainty. Requirements uncertainty has to do with variations stemming from changes in the configuration of the system you're analyzing. When you conceive a new system, its preliminary design seldom turns out to be exactly the same as the final design. Changes will take place in the requirements and characteristics of the system. Requirements change for economic, political, technological, and environmental reasons. Estimates for systems' costs historically relied upon the preliminary design information. If the preliminary characteristics of the system are in error, then early cost estimates relying upon those characteristics will be in error.

Technological Uncertainty. Technological uncertainty deals with the likelihood that the system cannot achieve the desired output. Technological uncertainty rarely is a serious problem in analyses of current operational problems. But as you try to peer further into the future, technological uncertainty becomes more important and can indeed dominate your analysis. Technological uncertainty is central in research and development decisions.

Statistical Uncertainty. Statistical uncertainty results from the chance element in recurring events. This is the kind of uncertainty that would persist even if you could predict the central values of all important parameters. For example, if you flip a penny a thousand times, it will come down heads about half of the time; but if you flip it only ten times, the proportion of heads may be much different. Given the impact of requirements uncertainty and technological uncertainty, statistical uncertainty is insignificant.

TREATMENT OF UNCERTAINTY

Now that you know that uncertainty does exist in economic analyses, what do you do about it? The most important advice is: Don't ignore it. To base an analysis and decision on some single set of best guesses could be disastrous. For example, suppose you are uncertain about ten factors and you make a best guess on all ten. If the probability that each best guess is 60 percent, the probability that all ten are right is about one-half of one percent (.6 x .6 x .6 x .6 x .6 x .6 x .6 x .6 x .6 x .6). If you confine your analysis to this best guess case, you ignore a set of futures with a 99.5 percent probability of occurring. Because uncertainties can have a significant impact on the results, you must design the analysis to reflect all major uncertainties. This usually means computing results for a number of contingencies. The number of cases to analyze and compute increases with each additional factor. Therefore the problem is to design the analysis to reflect only the most significant contingencies. You can use a number of techniques when dealing with uncertainty. Several of these techniques are:

Computer Simulation is one technique designed to assist you in making decisions under uncertainty. Assuming that you can assign probability distributions to each of the major cost determinants, you can construct a computer program to simulate what is likely to occur. In effect, the computer randomly selects one value from each of the relevant distributions, combines it with other values from other distributions, and produces an estimated value for the investment. The computer repeats this process for a number of trials. When finished with the runs, the computer can plot the relative frequency of the various values. While simulation can be very useful, the technique does require obtaining probability distributions for a number of variables and involves a fair amount of programming and machine time costs. Thus, full scale simulation is generally feasible for projects with extensive funding.

Sensitivity analysis is a somewhat less expensive simulation technique. It is an available alternative method of analyzing the outcomes of various projects or strategies. Instead of using probability distributions for each of the variables in the problem, you simulate the results by starting with the best guess estimate for each variable, then changing the values of the variables, within reasonable limits, to see the effects of the changes. This technique, known as sensitivity analysis, is considerably less expensive than the full scale simulation and provides data for decision making purposes.

Contingency analysis is a form of sensitivity analysis and involves evaluating the effect of new factors or conditions. You assess these new aspects by asking yourself questions of the type "what happens if...?" For example, after a comparison of two computer systems results in an established preference, you might ask "What happens if a company develops a new computer family in 5 years?" Or you might ask, "What happens if the company closes my department? Can I adapt the system to another operation?" The chance of an event occurring may be subjective or have assigned probability.

A Fortiori Analysis is a method you use to overcome your preconceived bias when comparing alternatives. A not uncommon situation involves replacement of a current, satisfactory production machine with new equipment. You may be quite hesitant to make the change since there is an element of uncertainty in the unknown performance of the new machine. Considering this uncertainty and the fact that the new machine is not essential as the old one is performing satisfactorily, you may want to dismiss the change with only perfunctory consideration. This could preclude superior performance. A Fortiori analysis is also rather perfunctory, resulting not in firm recommendations, but only in indications. Its use is dependent upon your realization of your inner bias. With this realization, you set the numerical values of any unknown in favor of the less desired alternative. That is, you counteract your bias for one alternative by favoring the other. For example, you would set minimum values for operating cost and maintenance downtime and a maximum value for production output of the new equipment. If, in this case, the eventual comparison of alternatives is favorable for the "old machine", the analysis assures you that your inner bias did not force the decision. However, if the comparison favors the new machine, you need to perform more evaluations to determine more realistic values of the variables.

CHAPTER 17

SENSITIVITY ANALYSIS

INTRODUCTION

Sensitivity is the relative magnitude of change in elements of an economic analysis that will cause a change in the ranking of alternatives. In a sensitivity analysis, if you vary one factor over a wide range without affecting the ranking of alternatives, you say that the analysis is insensitive. That means that the analysis is not very vulnerable to uncertainty surrounding that factor.

Contingency analysis is a special form of sensitivity analysis. It considers the potential impact of changes on the alternatives. Contingency analysis answers "what if" questions. For example, what if the economic life were 5 years instead of 8?

Sensitivity and contingency analysis do not require sophisticated techniques. They compel you to recognize and handle uncertainties in an economic analysis.

STEPS IN PERFORMING A SENSITIVITY ANALYSIS

First, you must determine if you need a sensitivity analysis at all. If one option is clearly superior to the rest, you do not need to test for sensitivity. When the choice is not clear amidst the uncertainty of future conditions, you must do a sensitivity analysis.

Sensitivity analysis should test the dominant input variables. That is, those having a major impact on the total present value costs or the benefits for a given alternative. Identification of the major cost contributors does not mean that you found the truly critical items. The choice of input variables may depend upon the degree of confidence
which you placed in these estimates. Some elements you scrutinize and evaluate are:

1. Cost Estimates. Increasing or decreasing major cost elements, that is, those which have a significant impact on the present value cost. Such cost may be the cost of renting equipment, the price you pay for labor, or the amount of supplies you consume as part of your operations.

2. Length of System Life. Shorter or longer system life.

3. Volume, Mix, or Pattern of Workload. Variation in the estimated volume, mix or pattern of work load.

4. Requirements. Changes in requirements resulting from either legislative mandate or changes in functional or organizational structure.

5. Configuration of Equipment or Software. Changes in configuration of hardware, software, data communications and other facilities.

6. Assumptions. Alternative assumptions concerning requirements, operations, facilities, or software, among others.

The basic procedure for sensitivity testing is fairly simple. Select a factor to test. Hold all parameters in the analysis constant except that factor. Rework the analysis using different estimates for the factor under consideration. Check the results. If the changes affect the ranking of alternatives, then the analysis is sensitive to that variable.

You should test each key parameter individually to determine its effect on the analysis.

Example 17-1

1. Given the following cost data, determine the less costly alternative:

	Alternative A (Proposed)	Alternative B (Status Quo)
Year One:		
ADPE	$ 80	0
System Development	100	0
Site Preparation	35	0
Years Two - Nine		
Personnel	$ 80/yr	$120/yr
Other Operating Costs	20/yr	25/yr

2. What if the system development costs are $130?

3. What if the system development costs are $120?

4. What if personnel costs increase to $85 per year?

Solution

1. The net present values for Alternatives A and B are:

$$PV_A = .954\ (\$80 + \underline{\$100} + \$35) + 5.088\ (\$80 + \$20)$$

$$= \$205 + \$509 \qquad = \underline{\$714}$$

$$PV_B = 5.088(\$120 + \$25) = \underline{\$738}$$

Alternative A, the proposed system, is less costly.

2. If system development costs are $130:

$$PV_A = .954(\$80 + \underline{\$130} + \$35) + 5.088(\$80 + \$20)$$

$$= \$234 + \$509 \qquad = \underline{\$743}$$

$$PV_B = 5.088(\$120 + \$25) = \underline{\$738}$$

Now, B costs less. You change the ranking and note the analysis is sensitive to a $30 increase in development costs.

3. If system development costs are $120:

$$PV_A = .954(\$80 + \underline{\$120} + \$35) + 5.088(\$80 + \$20)$$

$$= \$224 + \$509 \qquad = \underline{\$733}$$

$$PV_B = 5.088(\$120 + \$25) = \underline{\$738}$$

Alternative A remains less costly than B. Maintain the rankings and note the analysis is insensitive to a $20 increase in system development costs.

4. If annual personnel costs are increased to $85, then:

$$PV_A = .954\ (\$80 + \$100 + \$35> + 5.088(\$85 + \$20)$$

$$= \$205 + \$534 \qquad = \underline{\$739}$$

$$PV_B = 5.088(\$120 + \$25) = \underline{\$738}$$

Now, B costs more than A. Change the ranking and note the analysis is sensitive to a $5 increase in annual personnel costs.

SENSITIVITY AND BREAK-EVEN ANALYSIS

Break-even analysis is useful for determining the point at which a particular factor becomes sensitive. In Example 17-1, you can find a break-even point for each parameter by setting the cost equations for the two alternatives equal to each other and solving for the unknown variable. The unknown variable in each case is the factor you tested for sensitivity. The break-even points are:

System development break-even cost:

$$.954 (\$80 + x + \$35) + 5.088(\$100) = 5.088(\$120 + \$25)$$
$$.954x + \$110 + \$509 = \$738$$
$$.954x = \$119$$
$$x = \underline{\$125}$$

If system development costs are $125 and you hold all other costs at their original estimates, the alternatives will have equal present values. If system development costs are less than $125, you recommend the proposed alternative. If system development costs exceed $125, you recommend the status quo.

Personnel break-even cost:

$$.954(\$215) + 5.088(x + 20) = 5.088(\$145)$$
$$\$205 + 5.088x + \$102 = \$738$$
$$5.088x = \$431$$
$$x = \underline{\$84.7}$$

If personnel costs are $85 and you hold all other costs at their original estimates, the alternatives will have equal present values. If personnel costs are less than $85, you recommend the proposed alternative. If personnel costs are greater than $85, you recommend the current system.

PRESENTING THE RESULTS

You can use tables, charts and graphs to highlight the results of the sensitivity analysis. Graphs are particularly useful because they provide a visual interpretation of the results over a continuous range of possibilities.

Figure 17-1 depicts the sensitivity of the system development costs. The vertical axis represents the PV cost and the horizontal axis represents the system development cost. The intersecting lines represent PV costs for each alternative. The status quo remains constant at $738. Points A, B and C represent the present values for the proposed alternative when the system development costs are $100, $120, and $130. The point at which the two alternatives intercept is the break-even point. To the left of the break-even point the proposed system is cheaper and to the right the status quo is cheaper.

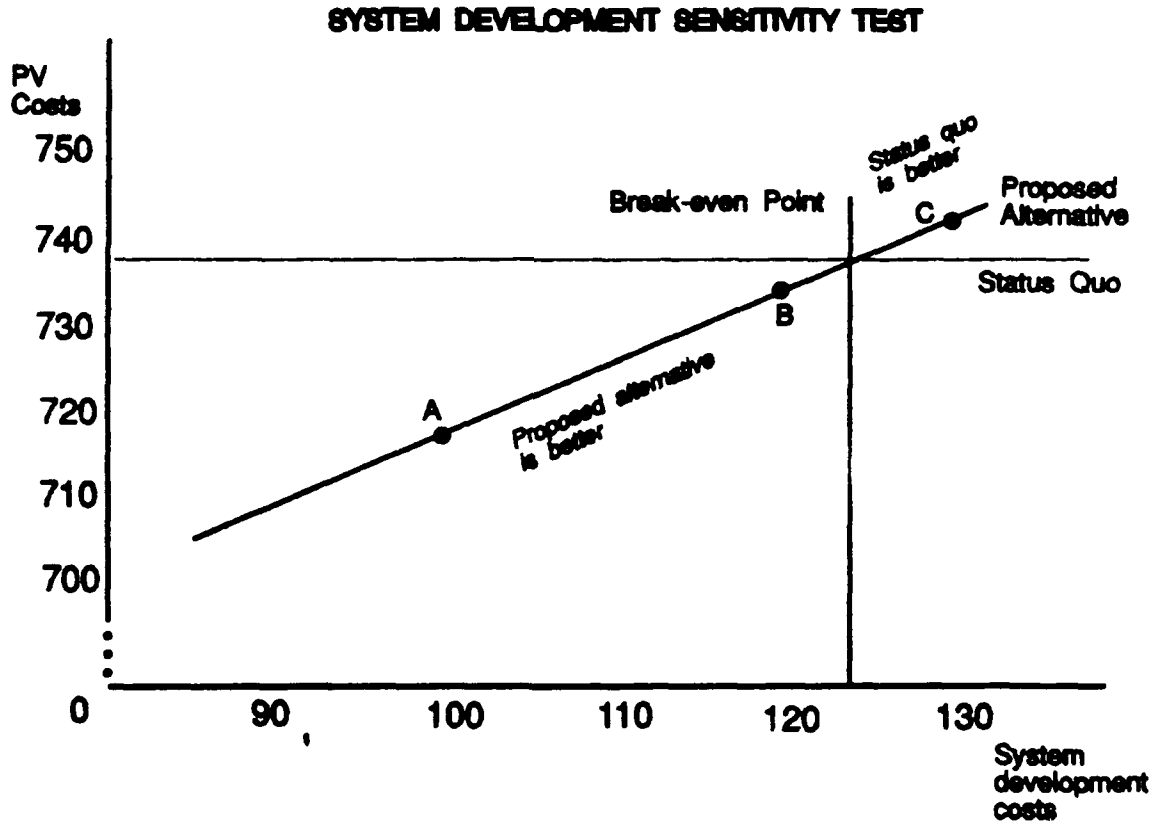


Figure 17-1

Similarly, Figure 17-2 plots the sensitivity of the annualpersonnel costs, where points A and B represent the present values when personnel costs are $80 and $85.

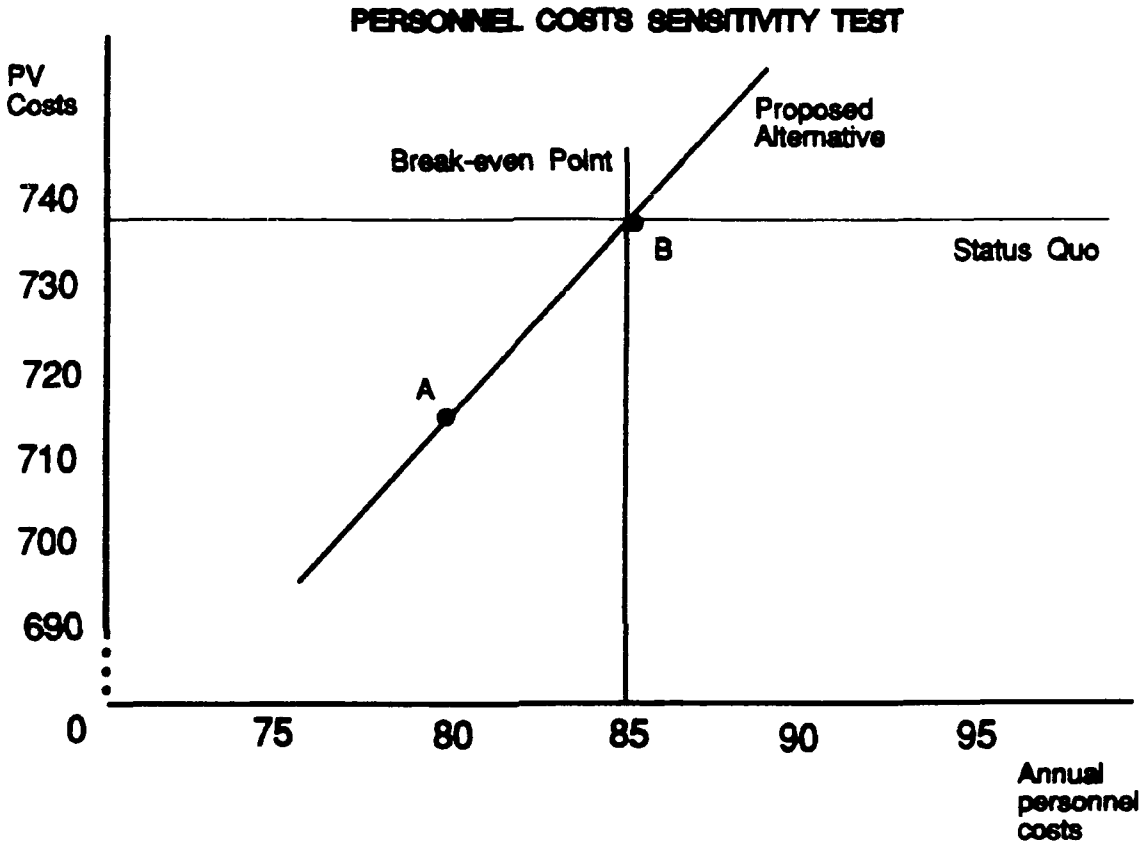


Figure 17-2

TWO VARIABLE SENSITIVITY TESTS

The outcome of an economic analysis is frequently sensitive to more than one input or assumption. You may extend the graphical techniques developed in the previous section to treat two variables simultaneously. For example, you can depict the PV life cycle cost of the proposed alternative in Example 17-1 for simultaneous variations in annual personnel costs and system development costs. If the system development cost is D and the annual personnel cost is P, total PV life cycle cost is:

$$PV = .954(80 + D + 35) + 5.088(P + 20)$$

Figure 17-3 shows plots of total PV life cycle costs for various combinations of system development and personnel costs. The horizontal axis represents personnel cost, P, and development cost, D, is treated as an exogenous variable. The lattice of PV life cycle cost points indicates which combinations of system development and personnel costs are preferable to the status quo. The circled point represents the "best guess". The original analysis used D = $100 and P = $80.

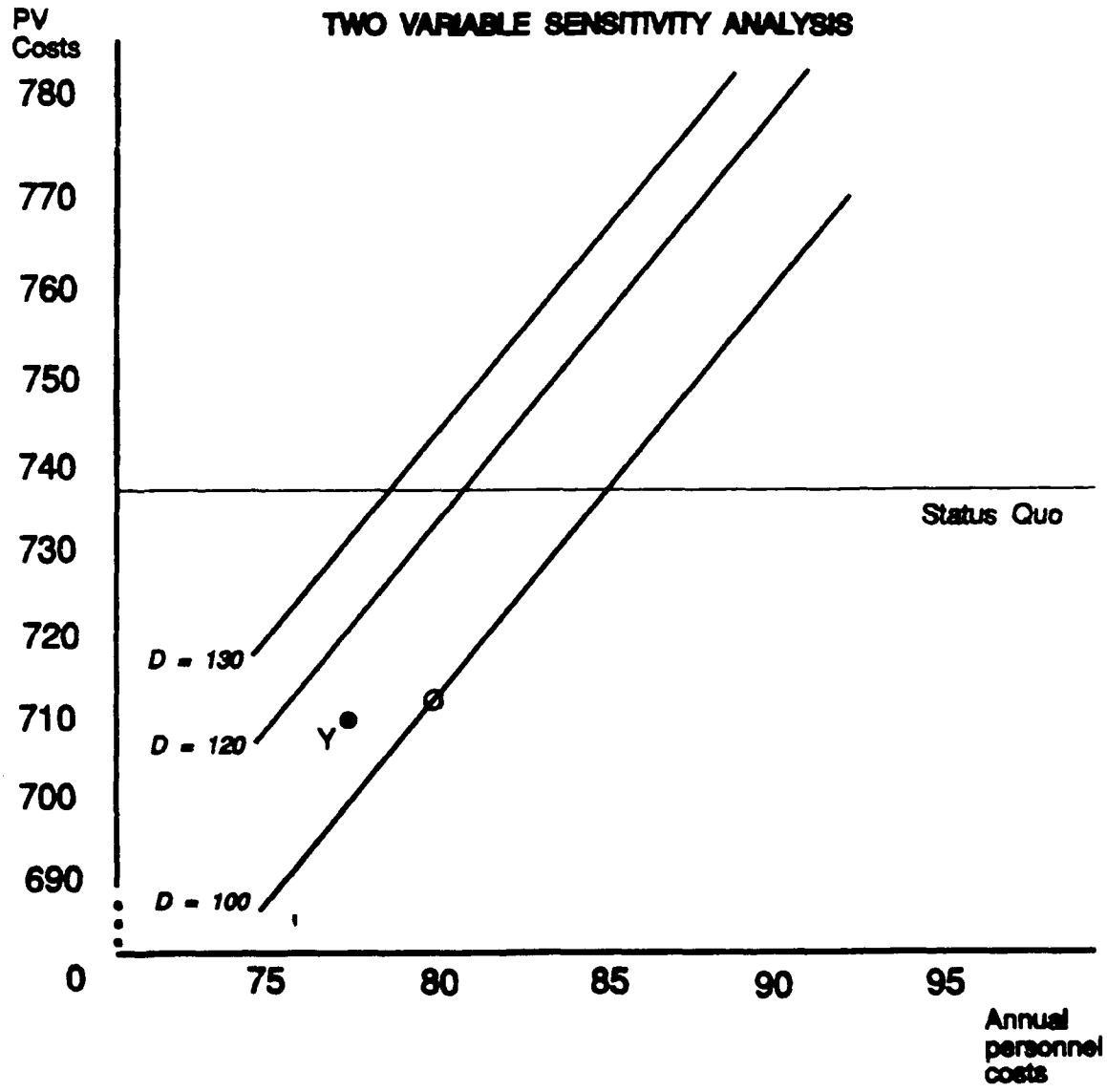


FIGURE 17-3

Inspection of the graph reveals if the proposed alternative is economically sound. It is sound if, and only if, the PV point for the proposed alternative lies below the status quo threshold. The graph also allows the reader to visually interpolate between designated development and personnel costs. For example, if the actual system development cost were $110 and the annual personnel cost were $77 the PV would be approximately $708 (see point Y in Figure 17-3).

GLOSSARY OF TERMS

Alternatives - The different courses of action, means, or methods by which you may obtain objectives.

Assets - Property, both real and personal, and other items having monetary value.

Assumptions - Explicit statements used to describe the present and future environment upon which you base the economic analysis. You make assumptions to support and limit the scope of the study.

Baseline Date - The start for the economic analysis, beyond this date decisions deal with future courses of action. It is the "today" in the analysis. You may call this the baseline year (or analysis year 0).

Benefits - Outputs or effectiveness you expect to receive or make over time because of making a proposed investment.

Benefit/Cost Ratio (BCR) - An economic indicator of efficiency, computed by dividing benefits by costs. When you quantify benefits in dollar terms, it is customary to discount both the benefit stream and the cost stream to reflect the present value of future costs and benefits.

Break-Even Analysis - A procedure for evaluating alternatives in terms of a common unknown variable. It involves solving for the value of the variable that will make the cumulative discounted costs for the alternatives equivalent; this value is the break even point.

Budget Estimate - Cost estimate prepared for inclusion in the DOD budget to support a system acquisition program.

Cash Flow Diagrams - A pictorial representation showing the magnitudes and timing of costs associated with an alternative.

Compound Interest - Interest you charge on both the original principal and its accrued interest.

Constant Dollars - Computed values that remove the effect of price changes over time. An estimate is in constant dollars if you adjust costs for all work so that they reflect the level of prices of a base year.

Contingency Analysis - A form of sensitivity analysis used to evaluate the effect of new factors or conditions in an analysis by asking "what if" questions.

Cost - The value of things used up or expended in producing a good or service. Usually you state costs in dollar terms. In economic analyses, a cost value need not coincide with the budget estimate.

Cost Avoidance - Savings realized by obviating a planned nonrecurring expenditure of resources. A cost avoidance can only occur when adopting an alternative other than the status quo.

Cost Benefit Analysis - A technique for assessing the range of costs and benefits associated with a given option, usually to find feasibility. Costs are generally in monetary terms, but benefits need not be in monetary terms.

Cost Estimate - Cost projection for expected transaction based upon information available.

Current Dollars - Level of costs in the year actual cost will be incurred. When you state prior costs in current dollars, the figures are the actual amounts paid. When you state future costs in current dollars, the figures are the actual amounts you expect to pay, including any amount due to future price changes.

Current Market Value - The amount for which an item could be sold in today's market. This can be the "going price" for a particular piece of used hardware in the open market or the trade-in allowance guaranteed by a particular manufacturer. Demand is greatest for computers that were once the most popular models--because there is a larger more receptive market. Obscure machines, on the other hand, have lower prices, though they are as good or better than the popular models.

Delphi Method - Technique for applying the informed judgement of a group of experts, using a carefully planned program of sequential individual interrogations, without direct confrontation; and with maximum use of feedback of digested information in the investigation and solution of problems. Usually, this has a series of repeated interrogations using questionnaires. After the initial interrogation of each individual, you use the answers from the preceding round of replies to supplement subsequent questioning. You encourage the expert to reconsider, change, or defend his previous answer considering the answers of the other members of the group.

Discount Factor - The multiplier for any specific discount rate that translates expected cost or benefit in any specific future year into its present value. Mathematically the discount factor is $1 / (1 + r)^n$ where r is the discount rate and n is the number of years since the date of the initiation of a program or project.

Discount Rate - A rate used to relate present and future dollars. You express this rate as a percentage and use it to reduce the value of future dollars in relation to present dollars to account for the time value of money.

Discounted Payback - A technique for determining the period over which accumulated present value savings are sufficient to offset the total present value investment costs of a proposed alternative to the status quo.

Discounting - A computational technique, using interest rates, to calculate the present value of future benefits and costs. Used in evaluating alternative investment proposals that can be valued in money.

Economic Analysis - A systematic approach to quantifying, portraying, and evaluating the relative worth of proposed projects. Economic analysis has six steps: stating tile objective; listing assumptions; defining the alternatives; determining costs and benefits; comparing and ranking alternatives; and performing a sensitivity analysis.

Economic Forecasting - Predicting the future movement of economic indicators.

Economic Life - The period over which you expect to accrue the benefits from a proposal. The economic life of a project begins the year the investment starts producing benefits and may be limited by its mission life, physical life, or technological life.

Effectiveness - The rate at which you progress toward the goal or objective of a program. Rate at which a program makes benefits.

Efficiency - The degree of optimization a program gives to its outputs. This pertains to both the productivity and the input mix.

Fixed Cost - That component of production cost that does not change if volume is within a specified range.

Fortiori Analysis - A technique used to overcome preconceived bias. You set the numerical values of unknowns to favor the less desired alternative. If the eventual comparison of alternatives still favors the "preferred" alternative, this assures you that your inner bias did not force the decision.

Fringe Benefits - Allowances and services provided to employees as compensation besides basic salaries and wages.

Historical Cost - The cost of any objective, based upon actual asset outlay, determined after the fact. Any method of cost determination may be used.

Imputed Cost - A cost that does not appear in accounting records and does not entail dollar outlays.

Incremental Cost - The additional resources needed to get some specific additional capability. Any cost you would incur despite which alternative you adopt is not an incremental cost. You need not include it in an analysis.

Industrial Engineering Method - Cost estimating technique where you consolidate estimates for various separate work segments into a total project estimate.

Inflation - A persistent rise in the general level of prices over time.

Intangible Benefits - Those improvements in system performance that cannot be quantified in terms of dollars or other measures.

Investment Cost - One-time costs associated with acquisition of real property, nonrecurring services, nonrecurring operations, and maintenance (start-up) costs and other one-time costs. Despite their one-time nature, investment costs may extend over periods of more than one year.

Lead Time - The period of elapsed time between initial funding or decision and the commencement of the economic life.

Life-cycle - The time from the beginning date of the project to the end of the program or project life.

Life-cycle Cost - The total cost to the Government of buying and owning a system over its full life. It includes the cost of development, acquisition, operation, support, and where applicable, disposal.

Mission Life - The period over which you anticipate a need for an asset,

Net Discounted Cost - Discounted dollar cost minus discounted dollar benefits. (This can be a negative value.)

Nonrecurring Cost - Costs that occur once; to be set apart from annually recurring costs.

Objectives - Goals or results that the decision maker wants to attain. It is the desired product or output of a program. The objectives justify the existence of the organization and its consumption of resources. You must state objectives in a way that does not preclude alternative approaches.

Opportunity Cost - The cost of forgone opportunities; the sacrificed amount of money, equipment, or units of production you could have used for another alternative with the same time and effort expended.

Output - The products, functions, tasks, services, or capabilities that an organization exists to produce, do, or maintain.

Output Measures - A useful description of functions, or missions, of an organization, expressed in relation to those assigned.

Parametric Cost Estimate - Estimate derived from statistical correlation of historic system costs with performance and physical attributes of the system.

Physical Life - The period when a machine, piece of equipment, or building physically can do its function.

Present Value - The estimated current worth of future benefits or costs derived by discounting the future values, using an appropriate discount rate.

Price Index - A percentage comparison of the total costs of a selection of commodities and services between two periods.

Program/Project - A major mission oriented agency endeavor that fulfills statutory or executive requirements. You define this in terms of the principal actions required to get a significant end objective.

Program Evaluation - An analysis of ongoing activities to find out how to improve an approved program/project based on actual performance. Program evaluation studies entail a comparison of actual performance with the approved program/project goals and objectives, and provide a basis for deciding whether the project meets its objectives in the most cost effective manner.

Project Life - The lead time and economic life.

Recurring Costs - Expenses for personnel, material consumed in use, operating, overhead, support services, and other items that recur annually in execution of a given program or work effort.

Savings Investment Ratio (SIR) - The ratio of discounted future cost savings to the discounted investment cost necessary to effect those savings. An SIR of one tells that the present value of the savings equals the present value of the investment.

Sensitivity Analysis - A technique for assessing the extent to which reasonable changes in assumptions or input variables will affect preference ranking of alternatives.

Simulation - Artificial generation of experimental processes to initiate or duplicate actual operational processes.

Sunk Cost - A resource that you use because of a prior decision. Because you irrevocably expend or commit to sunk costs, they do not affect your choice between alternatives.

Tangible Benefits - Those improvements in system performance that you cannot quantify. They do not include savings in recurring operating expenses; you reflect these savings as reductions in cost.

Technological Life - The estimated number of years before technology will make the existing or proposed equipment or facilities obsolete.

Terminal Value - The proceeds (less removal and disposal costs) you get when disposing of a tangible capital asset. Usually, you measure this by the net proceeds from the sale or other disposition of the asset, or its fair market value if you trade the asset for another asset.

Time Value of Money - A name given to the idea that the use of money costs money. A dollar today is worth more than a dollar tomorrow because of the interest costs related to expenditures and benefits that occur over time. Annual savings or cash inflows projected for tomorrow have present values less than their undiscounted dollar values.

Uniform Annual Cost (UAC) - A constant amount that, if paid annually throughout the economic life of a proposed alternative, would yield a total discounted cost equal to the actual present value life-cycle cost of the alternative.

Variable Cost - A cost that varies with the quantity of output produced.